FINAL REPORT

Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

ESTCP Project MM-0608

AUGUST 2007

Scott Millhouse
U.S. Army Corps of Engineers

Approved for public release; distribution unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
20-02-2008	Phase I Final Report	03/2006-08/2007

4. TITLE AND SUBTITLE
Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

5a. CONTRACT NUMBER

5b. GRANT NUMBER W912DY-06-2-012

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Scott Millhouse

5d. PROJECT NUMBER
ESTCP 200608

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

US Army Corps of Engineers
USAESCH, Huntsville
Box 1600
Huntsville, AL 35807-4301

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers
USAESCH, Huntsville
Box 1600
Huntsville, AL 35807-4301

10. SPONSOR/MONITOR'S ACRONYM(S)
USAESCH

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution not limited

13. SUPPLEMENTARY NOTES

14. ABSTRACT This project integrated an innovative robotic tow vehicle with industry standard Digital Geophysical Mapping (DGN) sensors and advanced geo-location positioning equipment to autonomously map target areas. The principle DGM tow vehicle is the Segway Robotic Mobility Platform (RMP) 4 wheel RMP 400 ATV configuration. Robot positioning is provided to centimeter accuracy by a commercial integrated DGPS/INS solution, the Novatel SPAN system with the high precision Honeywell HG1700 AG58 gyro. Trailer DGM sensor location was determined by geometric calculations based on tow bar hitch angles (as indicated by an optical encoder) and the fixed tow bar lengths and alternately by a second DGPS placed on the trailer. The demonstration proved that a robotic solution provides a more precise path following, a more consistent speed and greater productivity than by man towed equipment. The Phase I demonstration focused on integration and path following to precisely replicate target coverage for multiple runs with multiple sensors. The demonstration was performed at the Aberdeen Proving Grounds Standard UXO Demonstration Site's at the Calibration Lanes during May 14-22, 2007. The mass mapping demonstration was performed in the Open field to gain productivity, performance and costing data. We mapped the Calibration Grid- 14 times for 1.8 Hectare (10- coverage for the RMP 400, 3 for the manned and 1 with the XT). The Open Field was mapped as 5 grids by the RMP 400 for 2.3 Hectare with Grid 4 (.2 Hectare) mapped by both manned and the XT to gauge performance and productivity

15. SUBJECT TERMS
Robotics, Digital Geophysical Mapping, UXO

16. SECURITY CLASSIFICATION OF: Unclassified			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Scott Millhouse
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	UU	142	**19b. TELEPHONE NUMBER** *(include area code)* 256-895-1607

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Table of Contents

Acronyms

AEC	Army Environmental Center
APG	Aberdeen Proving Grounds
ATC	Aberdeen Test Center
AU	Auburn University
CEHNC	Corps of Engineers Huntsville Center
cm	Centimeter
DGM	Digital geophysical mapping
DGPS	Differential global positioning system
EM	Electro Magnetic
ESTCP	Environmental Security Technology Certification Program
ft	Foot
GHz	Gigahertz
GPS	Global positioning system
kbps	Kilo-bits per second
lb	Pound
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
m	Meter
mm	Millimeter
ms	Millisecond
mV	Millivolt
RMP	Robotic Mobility Platform
RMS	Root Mean Square
RTK DGPS	Real-time kinematic differential global positioning system
SPAN	Synchronized Position Attitude Navigation
UXO	Unexploded ordnance

Figures

Tables

Acknowledgements

Abstract

This project integrated an innovative robotic tow vehicle with industry standard Digital Geophysical Mapping (DGN) sensors and advanced geo-location positioning equipment to autonomously map target areas. The principle DGM tow vehicle is the Segway Robotic Mobility Platform (RMP) 4 wheel RMP 400 ATV configuration. Robot positioning is provided to centimeter accuracy by a commercial integrated DGPS/INS solution, the Novatel SPAN system with the high precision Honeywell HG1700 AG58 gyro. Trailer DGM sensor location was determined by geometric calculations based on tow bar hitch angles (as indicated by an optical encoder) and the fixed tow bar lengths and alternately by a second DGPS placed on the trailer. The demonstration proved that a robotic solution provides a more precise path following, a more consistent speed and greater productivity than by man towed equipment.

The Phase I demonstration focused on integration and path following to precisely replicate target coverage for multiple runs with multiple sensors. The demonstration was performed at the Aberdeen Proving Grounds Standard UXO Demonstration Site's at the Calibration Lanes during May 14-22, 2007. The mass mapping demonstration was performed in the Open field to gain productivity, performance and costing data. We mapped the Calibration Grid- 14 times for 1.8 Hectare (10- coverage for the RMP 400, 3 for the manned and 1 with the XT). The Open Field was mapped as 5 grids by the RMP 400 for 2.3 Hectare with Grid 4 (.2 Hectare) mapped by both manned and the XT to gauge performance and productivity. The total area mapped equates to 11 acres. Productivity was .43 acres per hour for the Calibration Lanes and .56 acres per hour for the Open Field. The operation met the basic performance objectives.

Full coverage of the open field was limited by the "water hazards" obstructions. These were areas where pits have been dug and the ground settled causing small 4-10" deep ponds. Since our equipment is not water proof, we designed the path following routines to avoid the hazards.

1. Introduction

1.1 Background

Unexploded Ordnance (UXO) poses a threat to both human life and the environment. Millions of UXO are located in the U.S. on active test and training ranges and Formerly Utilized Defense Sites (FUDS). In addition to the millions of UXO, there are many times more cultural and debris anomalies. Digital Geophysical Mapping (DGM) is used to map the areas and to locate, identify and select the items for sampling and removal. Many modes of DGM are utilized that include airborne and ground based platforms such as large towed arrays and man-portable equipment. All sites will need some amount of ground based mapping by man-portable or narrow width towed platforms depending upon terrain, ground cover and UXO objective. Man portable equipment essentially uses the operator as a "beast of burden" to carry the electronics and batteries and tow or swing the sensors in addition to monitoring the equipment and maintaining track. This can lead to reduced data quality due to deviation from pathway and inadequate sensor and position monitoring. Fatigue can cause reduced production and inattention to safety concerns. This effort tests and develops easily transportable battery powered tow vehicles that has been measured and documented for their effect on typical geophysical sensors.

New sensors, analysis techniques and field methodology are normally selected by a geophysical prove out process. Typically an area is seeded with the full range of expected Ordnance and Explosive items and clutter at a range of depths as a site specific evaluation or as part of a technology validation such as at the Yuma or Aberdeen Proving Grounds Standard UXO Technology Demonstration Sites. For the best comparisons the individual sensors should cover the same pathways as close as possible. This will facilitate analysis algorithm development and equipment performance validations. For this project all sensor suites being demonstrated traversed the site by being robotically towed to the same pathway with accurate positioning by INS enhanced DGPS.

Typical field mapping areas have varied terrain, obstacles, line-of-sight and horizon visibility. This adds challenges to maintaining a pathway and for maintaining sensor positioning. Semi-autonomous, autonomous and tele-operated mapping operations are desired for enhanced quality, personnel safety and production. Travel pathways can be designed to minimize interferences and for maximum production with the objective to survey all areas that are currently being covered by man portable towed sensors. For the most flexibility and production, autonomous obstacle recognition and avoidance and a methodology for maintaining track and positioning will be required for areas when the primary geo-location positioning system is shadowed.

1.2 Objectives of the Demonstration

We developed the Segway® Cross-Terrain Transporter (XT) and the two wheeled and four wheeled versions of the Robotic Mobility Platform (RMP), RMP 200 and 400, as a manned DGM and robotic narrow towed array DGM tow vehicles. The equipment was tested as a manned tow vehicle to define capabilities and limitations and then for both two and four wheeled operation as tele-operated and the RMP 400 for autonomous robotic operation. Our objective is a small, economic, environmentally clean easily shippable tow vehicle. Phase II adds capability

for more autonomous operation for larger less controlled locations by including obstacle recognition and avoidance and positioning and path following for when the primary positioning system is shadowed. Phase II will provide the capability to survey all areas that are typically surveyed by man towed sensors.

The vehicles were demonstrated and tested at the Aberdeen Proving Ground, MD Standardized UXO Site at the Calibration Lanes and Open Field areas. This effort mapped portions of the APG test area with two geophysical instrument configurations, EM-61 MK2 and a dual sensor G-858 total field magnetometer array use three towing methodologies. The EM was towed by the 4-wheel RMP 400 robot, manned by the XT ATV Segway and as man towed. The magnetometer was towed only by the 4-wheel RMP 400 robot. Positioning is provided by the Novatel DGPS with the (Synchronized Position Attitude Navigation) SPAN inertial augmentation. The testing demonstrated a high data quality due to more accurate senor placement and path following with greater productivity than man towed.

1.3 Regulatory Drivers

This project is primarily motivated by the desire for more efficient and accurate DGM operations, to achieve better technical performances at reduced cost. Precise path following and autonomous DGM operations will support faster, better and cheaper detection, characterization, and anomaly removal. Regulatory issues do not affect the need for this technology.

1.4 Stakeholder/End-User Issues

This demonstration documents the performance of a manned and robotic tow vehicle integrated with geophysical sensors. Results of this demonstration provides end-users with an understanding of the technical, logistical, and financial impact of these technologies and allows informed decision-making by end users for appropriate applications.

2. Technology Description

2.1 Technology Development and Application

The Segway® Cross-Terrain Transporter (XT) used for the manned operations is the latest self-balancing human transporter that provides enhanced performance on a variety of terrain with minimal environmental impact. The XT can self-balance because of a technology called dynamic stabilization. Dynamic stabilization works in much the same way your own sense of balance does. Where you have an inner ear, eyes, muscles, and a brain to keep you balanced, the XT has solid-state gyroscopes, tilt sensors, high-speed microprocessors, and powerful electric motors performing to keep it balanced. The systems sense your center of gravity, instantaneously assess the information, and make minute adjustments one hundred times a second.

The Robotic Mobility Platform (RMP) version of the XT is available in the typical 2 wheel mode as well as a dual unit with 4 wheels. The 4 wheel version provides the additional stability and traction for rough terrain applications of 4 individually powered wheels. This platform is based upon the mainstream commercial product except that it provides output to a generic PC external command control computer and takes instruction from that computer for maneuvering instead of relying upon the commercial manned product's manual control input. Instead of having a balancing rider providing direction by leaning or turn commands by the operation of a twist grip, the command computer communicates with the RMP by the USB bus interface at 100Hz. The unit supports a joystick control mode for remote operation as well as a control command set for robotic control.

The proposed Segway solutions meet our objectives for a small, economic, environmentally clean easily shippable tow vehicle for DGM.

Figure 2-1 Segway Robotic Mobility Platforms

The initial effort upon receipt of the Segway equipment was to establish wireless control communications with the robots. A custom interface based upon the Auburn University experience with the DARPA Grand Challenge was created to utilize the robotic command structure and to monitor performance. This was enhanced to allow remote joystick command control of the robots in preparation for conducting the noise study testing. The noise study (attached as Appendix D) was then performed with the robots remotely operated. They carried the full complement of equipment to determine instrument affects but none of it was actively

integrated. Based upon the noise study results, robotic development was focused to the 4-wheel RMP 400 robot.

Development then focused to create the autonomous path following capability for an open obstacle free environment. This included software development to generate desired routes and to direct and control the robot to maintain the route as well as the hardware development and integration. Tow vehicle hardware included the on-board computer, power, communications, video, USB hubs and the primary DGPS positioning system with the SPAN inertial augmentation. This was augmented by developing a unique tow bar solution that could be used for all vehicles. The tow bar floats along the ground and articulates so not to transmit uncontrolled force or movement to the geophysical sensor package from the tow vehicle. The tow system was completed by addition of an optical encoder to measure the hitch angle. Knowing the robot location, hitch angle and lever arm lengths permits precise calculation of the geophysical sensor location.

Figure 2-2 RMP 400- Note: Tow Bar, encoder, DGPS and 2 way communications
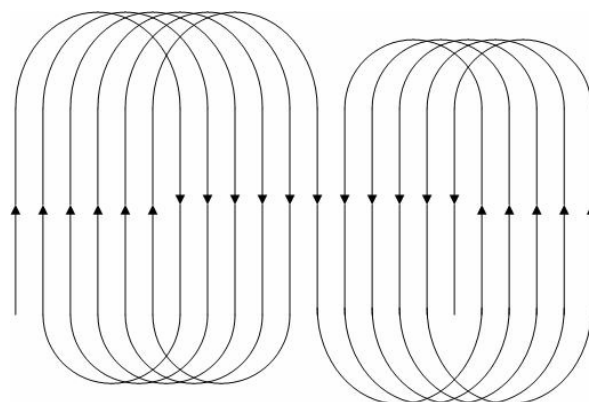
Figure 2-3 Autonomous path following- circuits to interleave lanes for full coverage

The robotic system was then integrated with an EM-61 geophysical DGM sensor and tested. Integration and software interface development was then incrementally developed and tested at the AU Solar House test area prior to the APG demonstration. Interface and timing between the geophysical sensors, DGPS and the robot is facilitated by the commercial Geometrics MagLogNT software package and custom software by AU. Flexible path planning software has been created that generates the robot routes for typical geometric shapes at user defined spacing and directions. This software was augmented to accommodate avoidance of known obstacles based upon the identified pits in the APG Open Field Area. See Figure 2-4 for the developed Graphic Users Interface showing robot survey data, planned and robot survey pathway, system status and video windows and Figures 2-5 & 2-6 for irregular pathway and obstacle avoidance design.
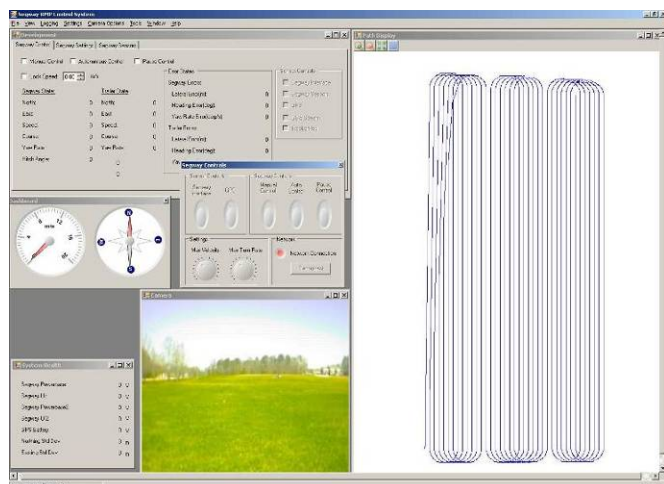
Figure 2-4 Graphic Users Interface- showing robot data, survey pathway, status and video windows
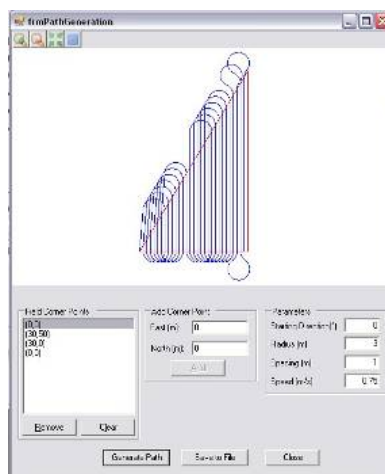
Figure 2-5 Irregular area path design
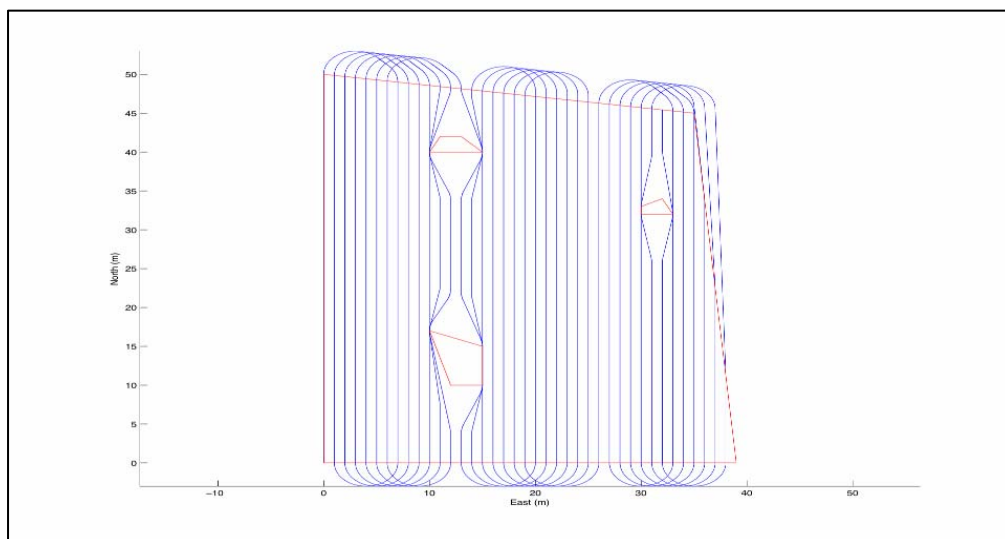
Figure 2-6 Obstacle Avoidance Path Design

2.2 Previous Testing of the Technology

Pre-project testing was performed with the standard Segway HT (Human Transport) commercial people mover in June-July 2005. We acquired an off-the-shelf refurnished HT and tested for the static and the dynamic effect of the ferrous and non-ferrous components and for production of Electromagnetic (EM) fields using the EM-61 and G-858 magnetometer instruments. These initial tests established a 2 m separation from the rear of the Segway to the center of geophysical sensors. There was essentially no difference between the static and dynamic affect from the HT. We then designed and build a tow system and tested at the McKinley Range, Huntsville AL test site. We tested by mapping grid 1 with an EM-61 towed by the manned HT. Data quality and production were similar to man towed. Based upon these results the manned towed and robotic effort was proposed.

Figure 2-7 Segway tow vehicle with EM-61 electronics and data pack/recorder at McKinley Range

The first field project effort was remote operation testing by wireless joystick of the RMP robots at Auburn University in June 2006. This was followed by the geophysical Noise Study testing performed at McKinley Range, Huntsville, AL also in June 2006. The noise study characterized the static and dynamic effect of the robots and manned XT to the EM-61 MK2 and the G-858 magnetometer for a Walk Away Test Area and for a Calibration Strip seeded with 3# practice bombs. These tests established the setback distances between the tow vehicle and sensor and helped to test robot control and dynamics. See Appendix D for the Noise Study report.

Figure 2-8 RMP 200 with EM-61   Figure 2-9 RMP 400 with G-858

The next significant field effort was the system integration testing held on 17 November 2006 at the Auburn University Solar House area, Auburn, AL. This was a comprehensive test where all the components were assembled into a system to create a geophysical map of a test area. A 30 meter by 80 meter (.4 acre) site was laid out with 17 OE items and simulates in size from sub-munitions to 81 mm. The site was surveyed autonomously by the system with the items on the surface in the North-South and East-West directions in the morning. The survey was repeated in the afternoon with the items buried (we were displacing the items during survey). The robot surveyed approximately 1.2 acres in 4 hours of operation on a battery charge.

Figure 2-10 Autonomous robot operation

Figure 2-11 AU Solar House Test Field
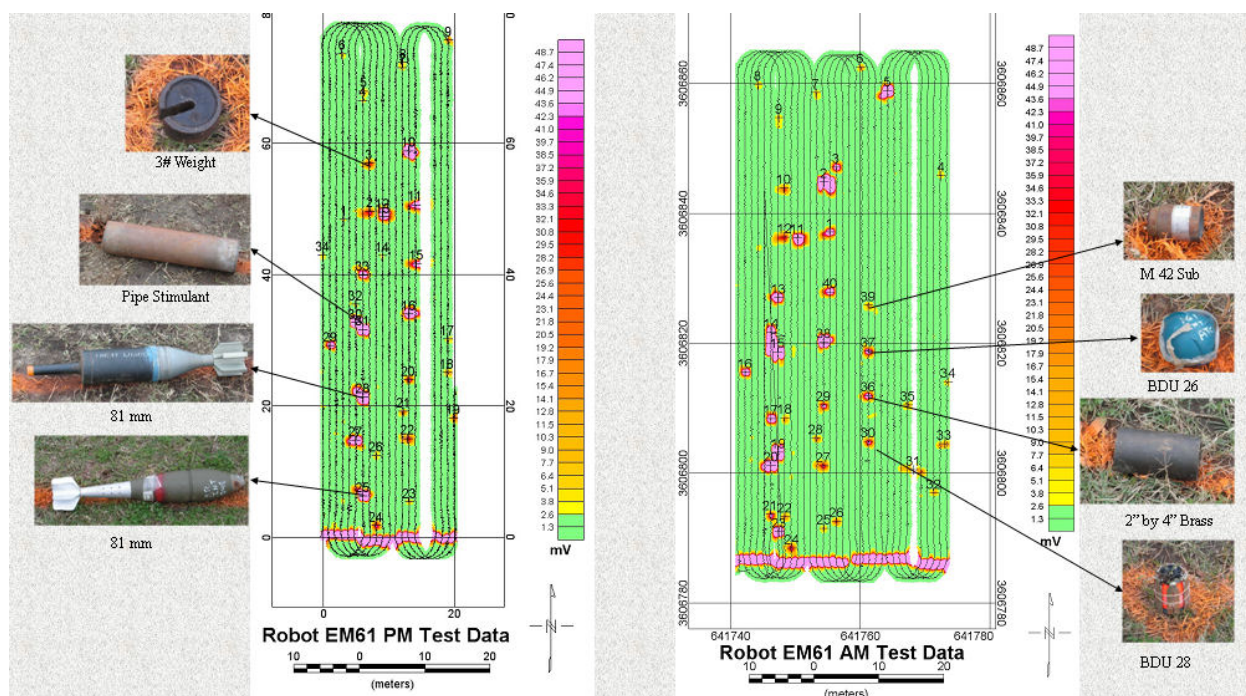
Figure 2-12 Solar House Integration test 17 November 2007

2.3 Factors Affecting Cost and Performance

Performance is bench marked against the speed, productivity and accuracy of man towed equipment based upon sample runs of the pathways by man towed equipment and by USAESCH's extensive experience for productions surveys. Costs and required man power is compared to current man towed applications. We recorded costs and productivity for the manned, man towed and robotic applications. This included items such as: a) daily/weekly/monthly technology costs for rental, purchase and maintenance b) technology availability and downtime considerations; c) survey productivity factors that include setup, survey area limitations, operating personnel labor requirements, cost and d) data processing for DGM.

2.4 Advantages and Limitations of the Technology

An advantage is higher data quality due to more accurately placement of the sensor package to the desired pathway. Another is increased productivity in acres per hour with less staff needed to perform DGM. This will more than offset the increased cost of equipment and complexity. There will also be less risk to personnel since they will not be on site walking the entire pathway. As the technology matures, a significant amount of DGM may be performed by remotely monitoring the system at safe distances.

At this stage of development, this technology will be limited to relatively flat open areas with identified obstructions that can be addressed by pathway planning for avoidance. We must leave gaps in data coverage that would have to be filled in by man towed, handheld or litter carried equipment. These gaps are not based upon characteristics of using a robot but upon the maneuvering characteristics of a vehicle towed array. These gaps at the APG demonstration are caused by water hazards created by sink holes in the Open Field Area. The gap extend was 2.3% of Grid 1, 7.2% of Grid 2 and 3.4% of the area of Grid 4.

3. Demonstration Design

3.1 Performance Objectives

Technical performance of the planned equipment is the primary issue to quantify in this demonstration. Table 3.1 outlines the objectives.

Type of performance objective	Performance criteria	Expected performance Accuracy
Quantitative	Production rate	.2-.5 acres/hr.
	Path following accuracy	.02-.20 m
	Battery life	2-4 hours
	Velocity change	<.5 mph
	Position accuracy	.01-.2 m
	Path coverage	80-100%
	Along line sampling spacing	.05- .2 m
	Across track lane spacing	+/- .05-.2 m
Semi-quantitative	System easy to setup by 2-person team	Yes or no
	System easy to operate by two-person crew	Yes or no
	Synchronization/Latency	Good- excellent
	*Induced Noise	Good- excellent

*Our goal is not increased from the baseline without the robots- noise and all performance is valuated by UXPROCESS

Table 3-1. Performance objectives.

3.2 Selecting Test Site(s)

Criteria for selecting a test site are the following:
1. Accessible to all project participants.
2. Sufficient open space with few obstructions for the planned tests.
3. Buried metallic targets that can be used to compare sensor data from multiple coverage with different sensor and equipment configurations.
4. Moderately level terrain so that elevation effects will not challenge the robotic path following.
5. A controlled site with locations of items unknown to the demonstrators so that it may be revisited to gauge improvement and compare to other technologies

Our selected test site was the Aberdeen Proving Ground (APG) UXO demonstration Site. It meets all these selection criteria.

3.3 Test Site History/Characteristics

The Standardized UXO Sites Program utilizes standardized test methodologies, procedures, and facilities to help ensure that critical UXO technology performance parameters such as detection capability, false alarms, discrimination, reacquisition, and system efficiency are accurate and repeatable. The Aberdeen Proving Ground, MD site is a 17-acre complex composed of 5 independently scored scenarios. The scenarios include calibration area, blind grid, wooded, moguls, and open field. Within the open field there are a variety of challenges to include electrical lines, gravel roads, fence line, wet areas, and clutter fields.

This test will utilize the Calibration and Open Field Areas as shown in the following figures:

1. Calibration Area
2. Blind Grid
3. Open Field
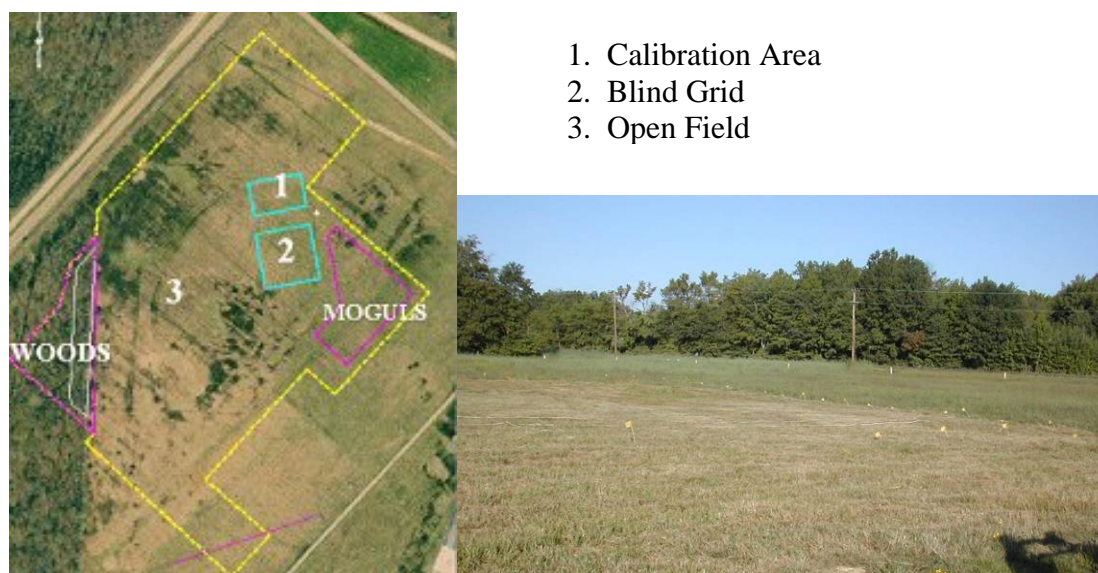
Figure 3-1 APG UXO Demonstration Site Layout, Calibration Lanes

3.4 Present Operations

The APG UXO Demonstration Site is maintained to provide quantitative, benchmarked evaluation of sensors and DGM systems and components. Prior demonstrations have been conducted at this facility under the supervision of AEC.

3.5 Pre-Demonstration Testing and Analysis

The performance of the systems was compared to the ground truth for the Calibration Lanes and to a previous demonstration.

3.6 Testing and Evaluation Plan

3.6.1 Demonstration Set-Up and Start-Up

This effort mapped portions of the APG test area with two geophysical instrument configurations, EM-61 MK2 and G-858 total field array and use three towing methodologies. The equipment was towed by the 4-wheel RMP 400 robot, the manned XT ATV Segway and as man towed. Positioning was provided by the Novatel DGPS with the SPAN inertial augmentation. This equipment was setup, configured and tested prior to shipping. It was loaded into a trailer partially assembled with spares and charging equipment and driven from Alabama to Aberdeen, Maryland for the demonstration surveys. Demonstration set-up used the trailer and the APG building bay for final assembly and check out. The only site requirement was for standard 110 v AC outlet power for battery charging. All equipment is battery powered and requires no external power.

3.6.2 Period of Operation

The demonstration effort at the APG UXO Test site was performed generally from 0730-1730 each day 14-22 May 2007 at both the Calibration Lane area and the Open Field. Preliminary data processing was performed daily on site with GEOSOFT with final GEOSOFT and UXPROCESS analysis performed following demobilization.

3.6.3 Area Characterized

The combined area mapped by the DGM equipment was 4.5 hectare (11.1 acres). This area included 10 surveys of the Calibration Lanes for 1.8 hectare and 2.3 hectare of the Open Field by the robot. Manned surveys were .5 hectare for 4 surveys of the Calibration Lanes and .4 hectare for 2 surveys of Grid 4 in the Open Field.

3.6.4 Residuals Handling

Not applicable. We acquired only geophysical data from the surface.

3.6.5 Operating Parameters of the Technology

- General: The Calibration Lane effort focused on testing multiple tow vehicles in various digital geophysical mapping sensor configurations for autonomous surveys. We towed the sensors to the same and alternate pathways at a high accuracy so that sensor responses can readily be compared. The Open Field effort demonstrated autonomous geophysical mapping in a production configuration to gauge system performance, production and cost.

- Calibration Lanes: The Calibration Lanes were established to gauge geophysical sensor performance for a sample of items sized from 20 mm and sub-munitions to 155mm at depths from 0.1-2.0 m for various orientations. The area seeded is 30 by 40 m for .12 Hectare (.3 Acre). The lane area was selected as a test location for tow system performance demonstrations for multiple reasons. The area is well documented with the locations of seeded items know as well as the conditions of emplacement such as depth and orientation. In addition the area has been surveyed by numerous examples of traditional geophysical sensor packages in similar configurations to our planned tow packages. This provides a general baseline for performance comparisons.

- This effort geophysically mapped the area with two instrument configurations, principally the EM-61 MK2 with a coverage of the Calibration Lanes with the G-858 total field array. The G-858 was demonstrated to show the flexibility to use alternate sensors with different tow bar lengths and trailer configurations. The sensors were towed by the 4-wheel RMP 400 robot at a one meter lane spacing parallel to the lanes principally in the North-South orientation. We focused to the North-South orientation because of the moisture sensor and test stand barriers on the east side of the Calibration Lanes. These obstructions made path following challenging in the E-W orientations requiring merging of several individual runs. To gauge the affect of tow vehicle dynamics and manual path following the EM-61 was also towed by the manned XT ATV Segway and as man towed.

- To investigate the affect of offset track pathways, the EM-61 MK2 was also towed by the RMP 400 at a .5 m offset from the lanes in the North-South orientation, parallel to the lanes in the East-West orientation and in the UTM grid North-South and East-West directions. This equals 10 passes of the Calibration Lanes area by the RMP 400. Where an orientation was mapped twice, generally one was solely by hitch angle sensor and the other augmented with trailer DGPS positioning. For comparison we also mapped the area 3 times by man towed with a coverage in the E-W grid by fiducial positioning and two using DGPS in the N-S Grid orientation at differing speeds. We also mapped it one time in the N-S Grid orientation by the manned XT. This gave us a total of 1.8 Hectares (4.5 acres) of coverage.

| | Tow method | | |
Instrument/direction	RMP 400	Manned XT	Man Towed
EM-61 N-S Grid	2	1	2
EM-61 N-S Grid .5 m offset	2		
EM-61 N-S True	2		
G-858 N-S Grid	1		
EM-61 E-W True	2		
EM-61 E-W Grid	1		
EM-61 E-W Grid- Fiducial			1

Table 3-2 Calibration Lane Survey Configurations

- Each of the geophysical data sets was processed by the GEOSOFT package to create a representation and dig lists. The data sets were independently evaluated by using the UX PROCESS QC/QA tools to evaluate quality. Areas evaluated included induced noise, position and track accuracy, synchronization/latency, path coverage, along line sample spacing, across-track lane spacing and velocity. The dig lists were compared to the known items in the Calibration Lanes to assess performance. See Appendix C for performance comparison data. The data was also compared to the Calibration Lanes baseline EM-61 good data set from the failure mode effort performed at APG in spring 2004 for ESTCP project 200131, GEOSOFT UX PROCESS development.

- Open Field Survey: To gain production cost and performance data 2.3 hectare (5.7 acres) of the open field area was mapped by the RMP 400 with the EM-61 MK 2 sensor package at 1 m lane spacing. See Figure 3-2 APG Site Layout. The area was subdivided into adjacent grids that maximize the lane

travel length for increased productivity as shown in Figure 3-3. Orientation was generally in the N-S direction based upon best direction of travel to cross perpendicular to the existing wheel ruts. The open field has a series of water hazards to work around with only one physical barrier, the chain link fence. The water hazards are low areas that do not drain consisting of pits created by settlement. Since the prototype equipment was not water proof we designated these areas as gaps in path coverage. We designed the robotic pathway to exclude and go around these obstacles. We determined the quality and percentage of coverage of the contiguous area by the GEOSOFT UXPROCESS tools. To gain additional data on productivity and the effect of alternate direction of travel we mapped an unobstructed subset of the Grid 1-4 area as Grid 5 as shown in Figure 3-4. It was mapped at approximately a 30 degree angle to the previous pathway in Grids 1-4. Grid 4 at .2 hectare (.5 acre) was also mapped with the EM-61 MK2 with the manned XT Segway as a tow vehicle and as man towed. Total Open Field area mapped was 2.7 hectare (6.7 acres). We compared the productivity and quality of the manned data sets to the autonomous robotic surveys.

Grid/ Positioning	Water Hazards	RMP 400	Tow method Manned XT	Man Towed
Grid1- Hitch Angle	No	1		
Grid1- DGPS	Yes	1		
Grid 2-DGPS	Yes	1		
Grid3-Hitch Angle	No	1		
Grid 4-Hitch Angle	Yes	1		
Grid4-DGPS	Yes	2	2	1
Grid5-DGPS	No	1		

Table 3-3 Open Field Survey Configurations

- The combined area mapped was 4.5 hectare (11.1 acres). Each of the geophysical data sets was processed by the GEOSOFT package to create a representation and dig list. The data sets were independently evaluated by using the UX PROCESS QC/QA tools to evaluate quality. Areas evaluated included induced noise, position and track accuracy, synchronization/latency, path coverage, along line sample spacing, across-track lane spacing and velocity.

Figure 3-2 APG Site Layout
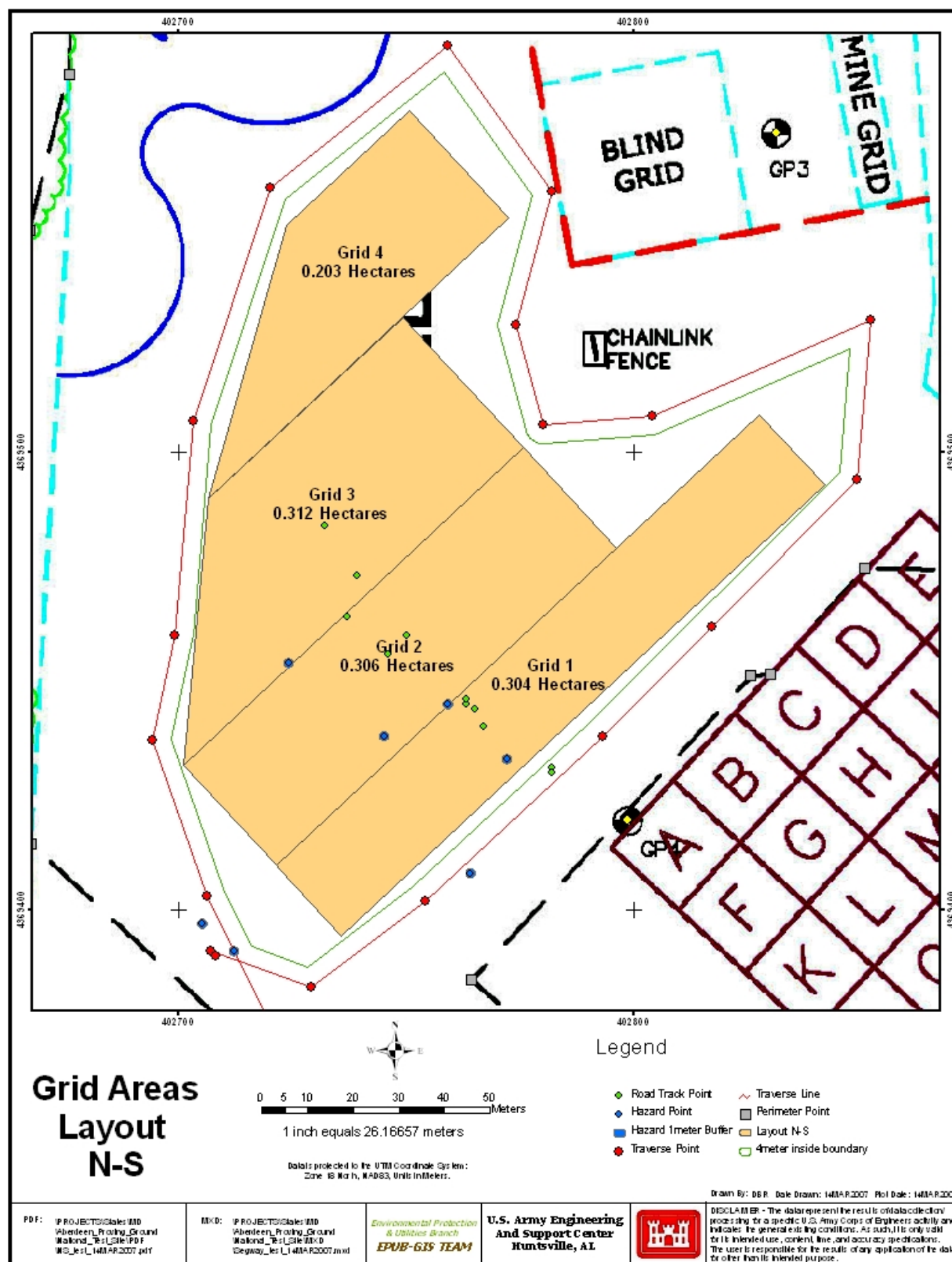
Figure 3-3 Open Field Survey Area Grids 1-4 Layout
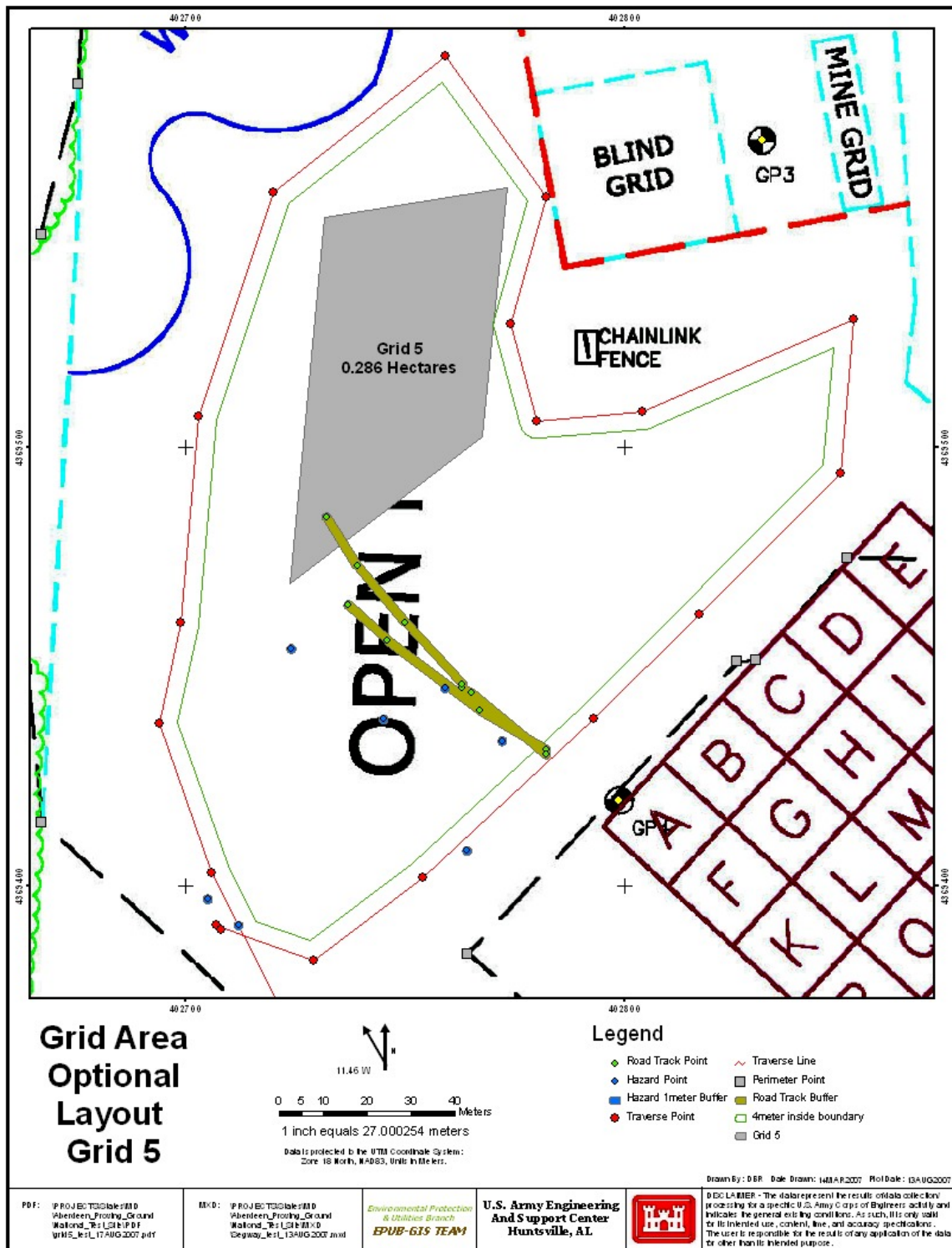
Figure 3-4 Open Field Survey Area Grid 5 Layout

3.6.6 Demobilization

Demobilization required repacking the equipment into the shipping trailer and departing the site.

3.7 Selection of Analytical/Testing Methods

This section is not applicable.

3.8 Selection of Analytical/Testing Laboratory

This section is not applicable.

4. Performance Assessment

4.1 Performance Criteria

The performance objectives in Table 3-1 define the criteria by which performance was evaluated by CEHNC. Table 4-1 provides the summarized results. Comments are provided for each item. Supporting data is included in section 4.3 under Data Analysis, Interpretation and Evaluation.

Type of performance objective	Performance criteria	Expected performance Accuracy	Actual
Quantitative	Production rate	.2-.5 acres/hr.	.43-.56 acres/hr
	Path following accuracy	.02-.20 m	.12 DGPS-.15 by hitch angle
	Battery life	2-4 hours	3.5 hours *
	Velocity change	<.5 mph	.42-.65 mph (1.39-1.79 manned)
	Position accuracy	.01-.2 m	.15 MagLogNT limitation **
	Path coverage (1m)	80-100%	85.4 % open- 94.6 % cal
	Path coverage (1.2 m)	> 90%	99.1 % open- 99.8 % cal
	Along line sampling spacing	.05- .2 m	.08 m (.16 m manned)
Semi-quantitative	System easy to setup by 2-person team	Yes or no	Yes
	System easy to operate by two-person crew	Yes or no	Yes – (1 person)
	Synchronization/Latency	Good- excellent	Excellent
	Induced Noise	Good- excellent	Excellent- very low

* Not tested to exhaustion- limit was USB Bus battery
** MagLogNT recorded position to minutes with 4 decimal places instead of 5

Table 4-1. Performance Results

Production rate: The demonstrated average production rate for the Calibration Lanes was .43 acres per hour with .56 acres per hour for the Open Field. The difference is cause by the percentage of time gathering survey data on the straight lanes as compared to maneuvering for the next lane. The calibration lanes were limited to 30 m of straight path until turns with the open field having straight paths up to 160 m long. Productivity is then directly related to velocity. We established the robots' velocity at .75 m/sec as a slow speed on purpose to assure data density and system longevity. We did not see the DGM data degrade in tests over 2 m/sec as shown in the noise study. We did witness considerable stress on all prototype components at the higher speeds and were concerned that without extensive system hardening we would have premature failures and be unable to complete our field efforts. Future efforts will attempt to double the speed to 1.5 m/sec for a productivity of 1 acre per hour using hardened components, connections and shock isolation.

<u>Path following accuracy:</u> Path following accuracy shows .12 m RMS error for the comparison of the design pathway location to the reported location of the DGPS position. This was tabulated from the surveys that included the DGPS antenna on the trailer as shown in Table 4-2.

Pathways within Grid Limits Only

		Design to DGPS on Trailer (Line Segments) Error		
Date	Run	Mean	Std. Dev	RMS
5/19/2006	OpenField Grid 5	-0.042	0.077	0.088
5/19/2006	CalGridMagEW	-0.043	0.119	0.127
5/19/2006	CalGridTrueEWPartial1	-0.049	0.126	0.135
5/19/2006	CalGridTrueEWPartial2	-0.067	0.112	0.131
5/19/2006	CalGridTrueNS	-0.027	0.108	0.110
5/20/2006	OpenField Grid 5 FillIn	-0.046	0.075	0.088
5/20/2006	Grid2NS	-0.026	0.148	0.150
5/20/2006	OpenField Grid 5 Cont	-0.031	0.089	0.094
5/21/2006	Grid1NS	-0.059	0.142	0.154
	Average	-0.043	0.111	0.120

Table 4-2. Path Following Results- Design to DGPS on Trailer

We believe actual deviations are less for a number of reasons. First the DGPS antenna is pitching in all directions with the trailer movement. Since the antenna is above the EM coils on a pole, each pitching movement cause the antenna to tilt and record a reading that is offset. There also are timing, synchronization and hardware issue with the EM-61 clock that limit accuracy. We used the commercial software product by Geometrics, MagLogNT, for the capture and synchronization of the positioning and geophysical data. This product requires DGPS position in the legacy format of Latitude and Longitude in degrees, minutes and decimal minutes instead of metric UTM. In post-processing we discovered that although we sent the positions to 5 decimal digits, MagLog NT only recorded them to 4. This provides an average deviation of up to .15 m. Analysis of position jumps verify the .15 m uncertainty.

Field observations did not show either the tow vehicle or robot deviating to this magnitude. Observation of resurvey of a grid show the robot and trailer followed the same tracks. This was verified by placing flags to mark the pathway as traveled for adjacent lanes and measurement of the spacing. The .20 m RMS error for hitch angle locations is from the DGPS reported location as shown in Table 4-3. With the uncertainty of the DGPS locations this error value is also suspect.

Table 4-4 shows the comparison between the design locations and as reported by the trailer position calculated from the hitch angle sensor positions. The error of .15 m was caused by changes in calibration and variable bias of the hitch angle sensor readings. This does not have the uncertainty associated with MagLogNT since we were not using the trailer DGPS but the Robot's as a basis for calculating trailer position. This error can be readily seen in the geophysical representations as gaps when we had the interleave lanes at locations changing rotation directions for Open Field Grids 1 & 3 on 5/16 and Grid 4 on 5/17. All except Grid 3 were resurveyed with the trailer DGPS positions for comparison. The gaps represented were shown not to exist when spacing was measured in the field.

Pathways within Grid Limits Only

		DGPS Trailer to Hitch Angle Sensor- Total Error		
Date	Run	Mean	Std. Dev	RMS
5/19/2006	OpenField Grid 5	0.164	0.082	0.082
5/19/2006	CalGridMagEW	0.172	0.065	0.184
5/19/2006	CalGridTrueEWPartial1	0.172	0.060	0.182
5/19/2006	CalGridTrueEWPartial2	0.159	0.059	0.169
5/19/2006	CalGridTrueNS	0.157	0.084	0.178
5/20/2006	OpenField Grid 5 FillIn	0.168	0.083	0.187
5/20/2006	Grid2NS	0.185	0.124	0.223
5/20/2006	OpenField Grid 5 Cont	0.210	0.385	0.439
5/21/2006	Grid1NS	0.171	0.089	0.192
	Average	0.173	0.114	0.204

Table 4-3 Path Following Results- DGPS on Trailer to Hitch Angle Reported Position

Pathways within Grid Limits Only

		Design to Hitch Angle Sensor Error (Line Segments)		
Date	Run	Mean	Std. Dev	RMS
5/19/2006	OpenField Grid 5	-0.119	0.062	0.134
5/19/2006	CalGridMagEW	-0.105	0.082	0.133
5/19/2006	CalGridTrueEWPartial1	-0.109	0.084	0.137
5/19/2006	CalGridTrueEWPartial2	-0.108	0.099	0.146
5/19/2006	CalGridTrueNS	-0.115	0.120	0.166
5/20/2006	OpenField Grid 5 FillIn	-0.149	0.060	0.160
5/20/2006	Grid2NS	-0.099	0.162	0.190
5/20/2006	OpenField Grid 5 Cont	-0.118	0.071	0.138
5/21/2006	Grid1NS	-0.131	0.116	0.174
	Average	-0.117	0.095	0.153

Table 4-4 Path Following Results- Design to Hitch Angle Reported Position of Trailer

Battery life: Battery life is shown at 3.5 hours but we never tested fully to exhaustion. We tested in a morning and afternoon session and exchanged batteries in between after approximately 3.5 hours of continuous use. There are four separate battery power systems as follows:

1. Segway RMP 400 power-packs. These are two lithium-ion 78 volt sealed units per drive (two front and two back) with factory claimed service of 4-6 hours.
2. Odyssey high performance 12v sealed lead acid for the DGPS/INS, brick computer and communications. At 3.5 hours it was nearly exhausted with system shutdown occurring at 4.5 hours.

3. Odyssey high performance 12v sealed lead acid for the EM-61 MK2- life in excess of 6 hours.
4. Robot USB bus power battery. This battery is hardwired into the robot control system. Twice in an afternoon session we shutdown a drive unit and were puzzled since the power-packs showed a charge. We thought the USB battery was being charged by the main power packs in operation. After the demonstration, Segway confirmed that it was only charged by the overnight charger. We added fresh power-pack batteries mid day and this battery exhausted after total system operation of around 6 hours, the factory claimed service life.

Velocity change: Velocity change would appear to be outside our objective of .5 mph at the reported .42-.65 mph standard deviation. The change is computed by the UXPROCESS GEOSOFT tools. The tools use every point (at .08 m intervals) to compute the velocity and change in velocity based upon the reported trailer positions. We feel that we are magnifying the minor instantaneous velocity changes caused by the terrain effect and the DGPS inaccuracy (including antenna pitching) to arrive at an incorrect velocity change. The robot velocity remains constant in a straight line with only minor deviations due to terrain. As an example the straight line calculated velocity was consistently shown at 1.74 mph in both the Open Field and the Calibration Lanes. In comparison, the velocity change for the manned surveys showed a 1.39-1.79 mph deviation even with a wider point spacing of .16 m.

Position accuracy: As stated in Path Following we believe our position accuracy is limited to .15 m due to the MagLogNT limitation for surveys using the trailer DGPS and also .15 m for the surveys using the hitch angle sensor to predict trailer locations.

Path coverage (1.0 m): Using a coverage width of 1.0 m we averaged 85.4% of the area coverage in the Open Field and 94.6% in the Calibration Lanes. The area remaining is caused by the deviations in path (but most likely in position accuracy) that leaves long narrow sliver strips where the sensor footprint did not pass. This value is suspect because of the problems with reported position accuracy and also by the manner that GEOSOFT calculates gaps. GEOSOFT calculates gaps based upon full coverage of their rectangular processing cells. Since the paths are all oblique to these cells, partial cell coverage is tagged as a gap.

Path coverage (1.2 m): Using a coverage width of 1.2 m we averaged 99.1 % of the area covered in the Open Field and 99.8 % in the Calibration Lanes. The increase in footprint eliminated the problem of the long narrow sliver strips of gaps and the partial cell GEOSOFT reporting calculation uncertainty. It is widely recognized that an EM-61 MK 2 effective footprint of coverage is greater than 1.0 m in width for all but the smallest of items. I have not been able to locate any data that relates coverage extent with target item size and depth to support using 1.2 m for establishing coverage but discussion with ERDC experts validate that a 1.2 m footprint is conservative for all but the smallest of items at the EM-61 detection limit.

Along line sampling spacing: Along line sampling spacing was consistently shown to be .08 m for the robotic surveys and .16 m for the manned surveys. This is validated by the slower speed of travel and consistent speed of the robot.

System easy to setup by 2-person team and system easy to operate by two-person crew: The system was easy to setup by a 2-person team. Initial assembly is facilitated by having two people due to the robot weight and trailer lengths but it could be done by one with proper planning and equipment setup. Once the system is operational only one person is required for daily operations such as joystick control movement to the survey grid, battery and data maintenance, path setup and system monitoring.

Synchronization/Latency and Induced Noise: Both were reported as excellent as compared to manned and other tow methodologies dues to the consistent speed and path tracking and the low noise of the robot due to little ferrous materials and low EM emissions.

4.2 Performance Confirmation Methods

Performance was evaluated by comparison of the performance for the various system configuration demonstrations as outlined in Section 3.6.3. The geophysical data was independently evaluated by using the GEOSOFT UXPROCESS QA/QC software. The dig lists were compared to the known items in the Calibration Lanes to assess performance. The data was also compared to the Calibration Lanes baseline EM-61 good data set from the failure mode effort performed at APG in spring 2004 for ESTCP project 200131, GEOSOFT UX PROCESS development.

4.3 Data Analysis, Interpretation and Evaluation

Each of the geophysical data sets was initially processed by the GEOSOFT package to create a representation and validate coverage while at APG. The data sets were then independently evaluated by using the UX PROCESS QC/QA tools to evaluate quality and to create the dig lists. Geophysical representations and dig lists for all surveys and areas are included in Appendix C along with comparison to the known locations for the Calibration Lanes. The tabulated evaluation results are provided here along with example data representation and typical photos of the surveys. Areas evaluated include induced noise, position and track accuracy, synchronization/latency, path coverage, along line sample spacing, across-track lane spacing and velocity.

Calibration Lane Survey:

Figure 4-1: Tow Vehicles

Top left- EM-61 MK2 with trailer DGPS towed by the RMP 400 Robot

Top right- EM-61 Towed by manned Segway XT

Lower right- G-858 total field magnetometer array towed by robot

Lower left- Maintenance, swap out of robot batteries.

RMP400 Robot-towed EM61MK2
5/18/07, Grid NS
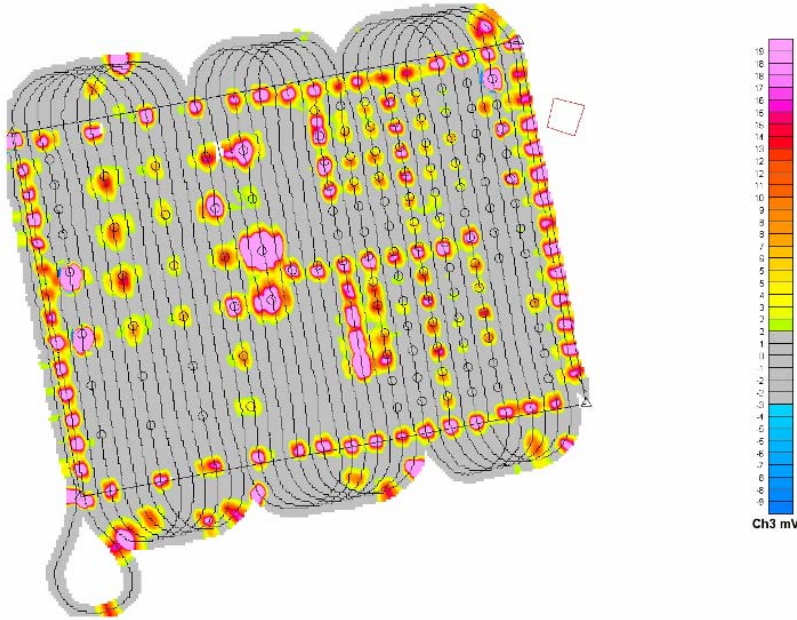
Man-Portable EM61MK2
5/21/07, Grid NS
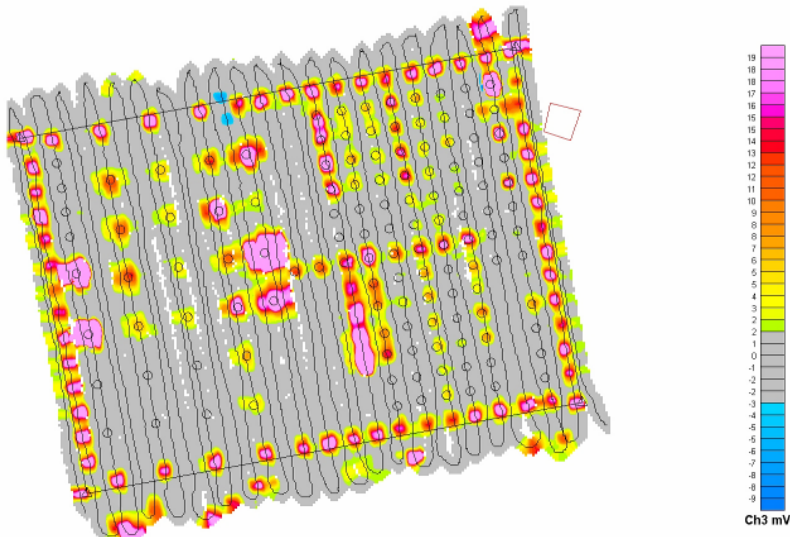
Figure 4-2:
Geophysical Data Representations-

Robotic and man towed surveys of the Calibration Lanes in grid N-S direction

APG Calibration Grid
RMP400, EM61-MK2, True EW
19May2007
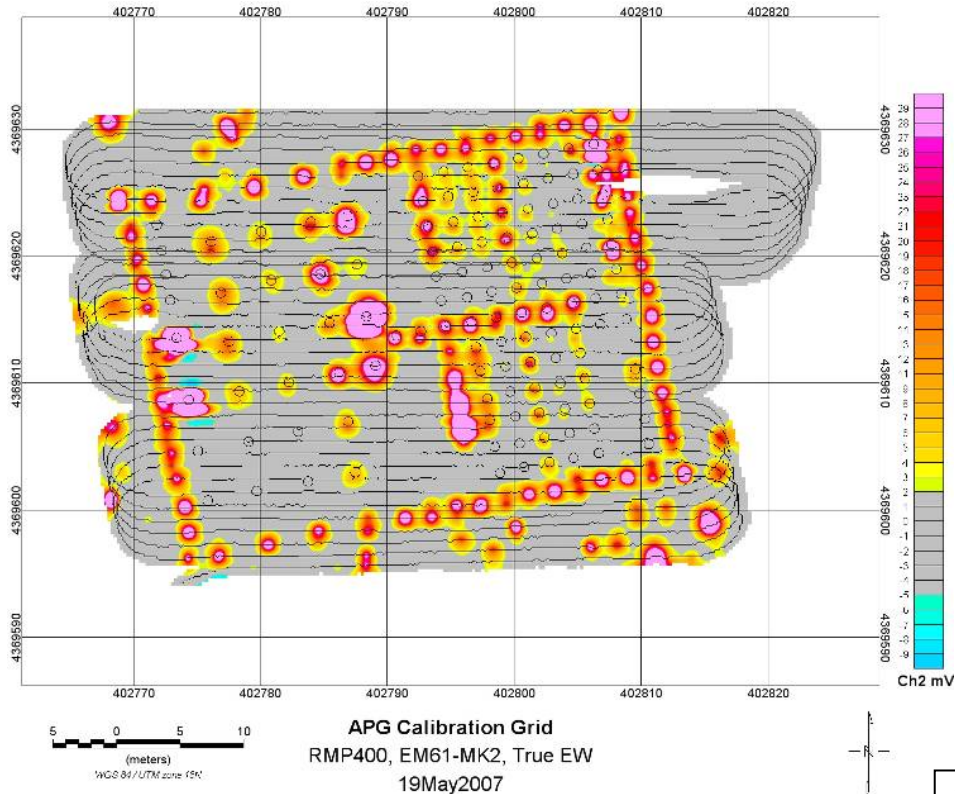
Figure 4-3:
Geophysical Data Representations-

Robotic surveys of the Calibration Lanes in true E-W and true N-S directions with the EM-61
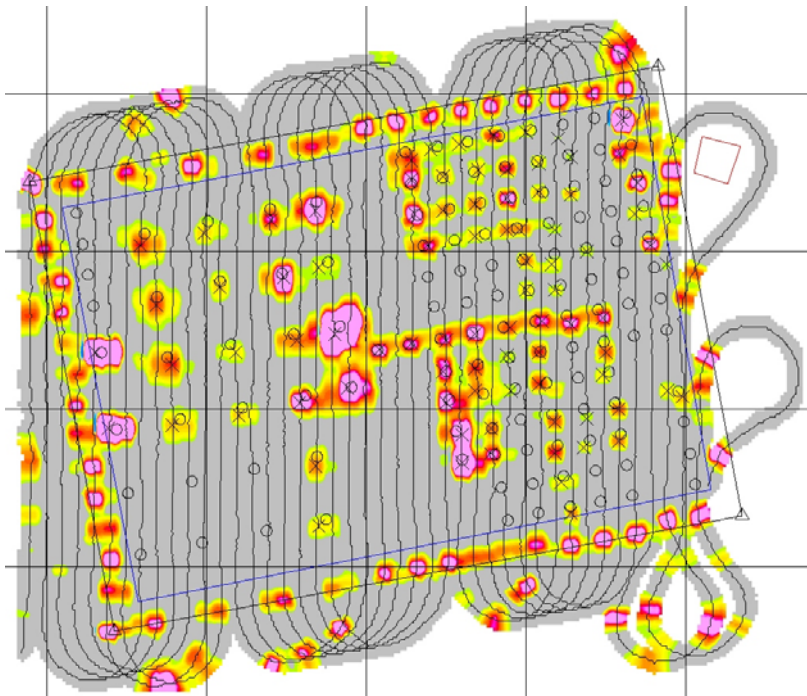
Table 4-5 Calibration Lanes Evaluation Summary Table 1

Calibration Grid: (1160.73 m^2 - area within rebar corners)

					(ucelatency, ucedrift)		(ucewindowstats)	(ucevelocity)

Date	Platform	Orientation	Processing Steps	4 or D?	Bkg Standard Deviation	Velocity (mph)	Velocity (mph) [manual calc from one line]
5/15/07	RMP, hitch angle sensor	GridNS, Offset from items	2 XY flyers deleted, drift corr, 0.3 latency	4	Ch2Lev: 0.61, Ch3Lev: 0.41	SD: 0.42, mean: 1.68	1.73
5/15/07	RMP, hitch angle sensor	TrueNS	drift corr, 0.3 latency	4	Ch2Lev: 0.57, Ch3Lev: 0.36	SD: 0.56, mean: 1.61	1.74
5/15/07	RMP, hitch angle sensor	True EW	drift corr, 0.3 latency	4	Ch2Lev: 0.69, Ch3Lev: 0.40	SD: 0.43, mean: 1.67	1.73
5/18/07	RMP	Grid NS	drift corr, 0.3 latency	4	Ch2Lev: 0.65, Ch3Lev: 0.37	SD: 0.59, mean: 1.79	1.74
5/19/07	RMP	Grid EW	drift corr, 0.3 latency	4	Ch2Lev: 0.67, Ch3Lev: 0.40	SD: 0.53, mean: 1.83	1.75
5/18/07	RMP	Grid NS Offset	drift corr, 0.3 latency	4	Ch2Lev: 0.58, Ch3Lev: 0.37	SD: 0.59, mean: 1.82	1.74
5/19/07	RMP	True EW Part1	drift corr, 0.3 latency	4	Ch2Lev: 0.66, Ch3Lev: 0.44	SD: 0.53, mean: 1.81	1.75
5/19/07	RMP	True EW Part 2	drift corr, 0.3 latency	4	Ch2Lev: 0.54, Ch3Lev: 0.33 (note: different bkg area polygon)	SD: 0.65, mean: 1.72	1.72
5/19/07	RMP	True EW Merged (part 1&2)	merged final part 1 & 2 gdbs	4		SD: 0.58, mean: 1.78	

5/19/07	RMP	True NS	drift corr, 0.3 latency	4	Ch2Lev: 0.78, Ch3Lev: 0.36 (note: includes negative spike in Ch2)	SD: 0.47, mean: 1.76	1.74
5/18/07	Man Portable	Grid NS	drift corr, 0.4 latency	D	Ch2Lev: 0.84, Ch3Lev: 0.89	SD: 1.39, mean: 2.37	2.48
5/21/07	Man Portable	Grid NS	drift corr, 0.5 latency	4	Ch2Lev: 0.95, Ch3Lev: 0.51	SD: 1.50, mean: 3.04	3.24
5/21/07	XT	Grid NS	deleted bad gps points (quality '1' & jumping over); drift corr, 0.4 latency	4	Ch2Lev: 1.37, Ch3Lev: 0.82	SD: 2.15, mean: 3.49	4.11
5/14/07	Man Portable	Grid EW Fiducial	converted to UTM, drift corr, 0.35 latency	D	Ch2Lev: 0.69, Ch3Lev: 0.43		2.85

Notes:
1. Column 5 specifies if 4 gates of the EM-61 bottom coil or 3 from the bottom and the top for a differential was used in evaluations.
2. Column 6 specifies the background standard deviations
3. The velocities in column 7 and 8 differ due to how they were calculated. Column 7 uses all points along the line by GEOSOFT (generally at .08 m spacing). The velocity in column 8 is calculated by using the end points of the straight lines within the grid.

Table 4-6 Calibration Lanes Evaluation Summary Table 2

Calibration Grid: (1160.73 m² - area within rebar corners)

(ucedatasep) (ucefootprintcov)

Date	Platform	Orientation	Sample Separation (% points >0.2m)	Footprint Coverage (1m)	Area Covered (inside rebar) [m²]	Gaps [m²]	Total Area Covered (including turns) [m²]	Footprint Coverage (% at 1.2m) in subset of area with full coverage, to check lane spacing	Time (min:sec)
5/15/07	RMP, hitch angle sensor	GridNS, Offset from items	0%, SD: 0.02; mean: 0.07	96.99%	1125.82	34.91	1390.39	99.92%	34:59
5/15/07	RMP, hitch angle sensor	TrueNS	0%, SD: 0.02; mean: 0.07	95.12%	1104.03	56.70	1509.5	99.42%	38:26
5/15/07	RMP, hitch angle sensor	True EW	0%, SD: 0.02; mean: 0.07	89.20%	1035.34	125.39	1179.46	99.28%	29:54
5/18/07	RMP	Grid NS	0.1%, SD: 0.03; mean: 0.08	97.26%	1128.88	31.85	1475.2	99.99%	37:42
5/19/07	RMP	Grid EW	0%, SD: 0.02; mean: 0.08	87.41%	1014.64	146.09	1435.13	99.97%	35:13
5/18/07	RMP	Grid NS Offset	0.1%, SD: 0.03; mean: 0.08	97.57%	1132.48	28.25	1567.54	99.89%	39:42
5/19/07	RMP	True EW Part1	0%, SD: 0.02; mean: 0.08	72.37%	840.00	320.73	1230.74	100.00%	30:30
5/19/07	RMP	True EW Part 2	0.1%, SD: 0.03; mean: 0.08	34.63%	401.95	758.78	755.78	100.00%	19:56
5/19/07	RMP	True EW Merged (part 1&2)	0%, SD: 0.02; mean: 0.08	97.29%	1129.31	31.42	1850.63		50:26
5/19/07	RMP	True NS	0%, SD: 0.02; mean: 0.08	96.19%	1116.50	44.23	1545.71	99.95%	38:50
5/18/07	Man Portable	Grid NS	12.5%, SD: 0.07; mean: 0.12	93.14%	1081.05	79.68	1418.49	99.42%	25:32

5/21/07	Man Portable	Grid NS	23.8%, SD: 0.10; mean: 0.16	85.69%	994.65	166.08	1264.07	94.80%	19:0
5/21/07	XT	Grid NS	27.6%, SD: 0.12; mean: 0.17	85.83%	996.28	164.45	1550.5	96.02%	21.17
5/14/07	Man Portable	Grid EW Fiducial	17.7%, SD:0.06 ; mean: 0.14	97.74%	1134.50	26.23	1204.8	98.81%	30.04

Open Field Geophysical Surveys

Figure 4-4: Robot-Open Field

Top- Robot with EM-61 in Open Field

Bottom- Water Hazards (Obstacles/ Data gaps)
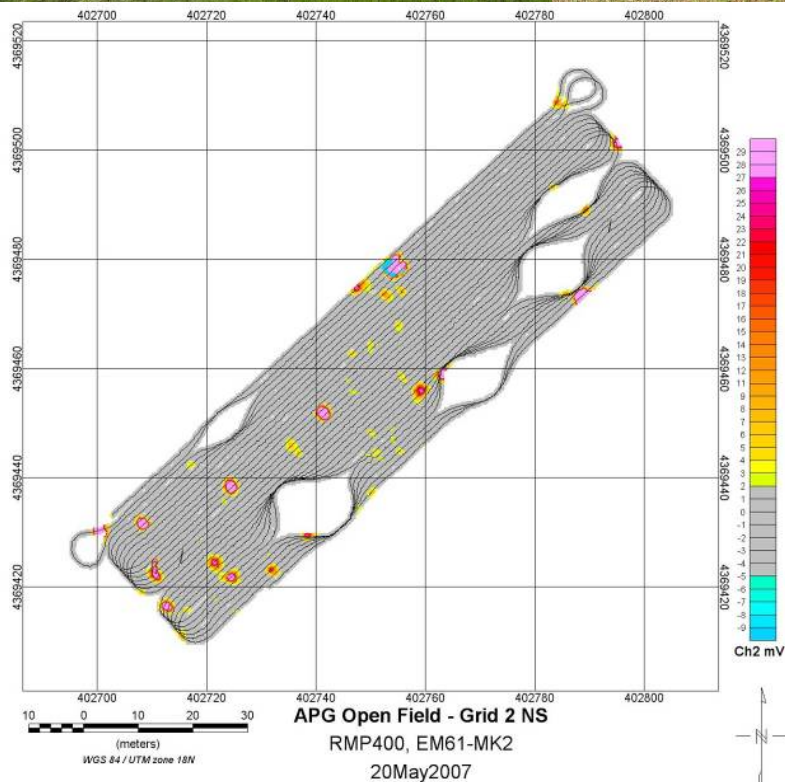
Figure 4-5: Obstacle Survey Typical obstacle avoidance- water hazard data gaps.

APG Open Field - Grid 2 NS
RMP400, EM61-MK2
20May2007
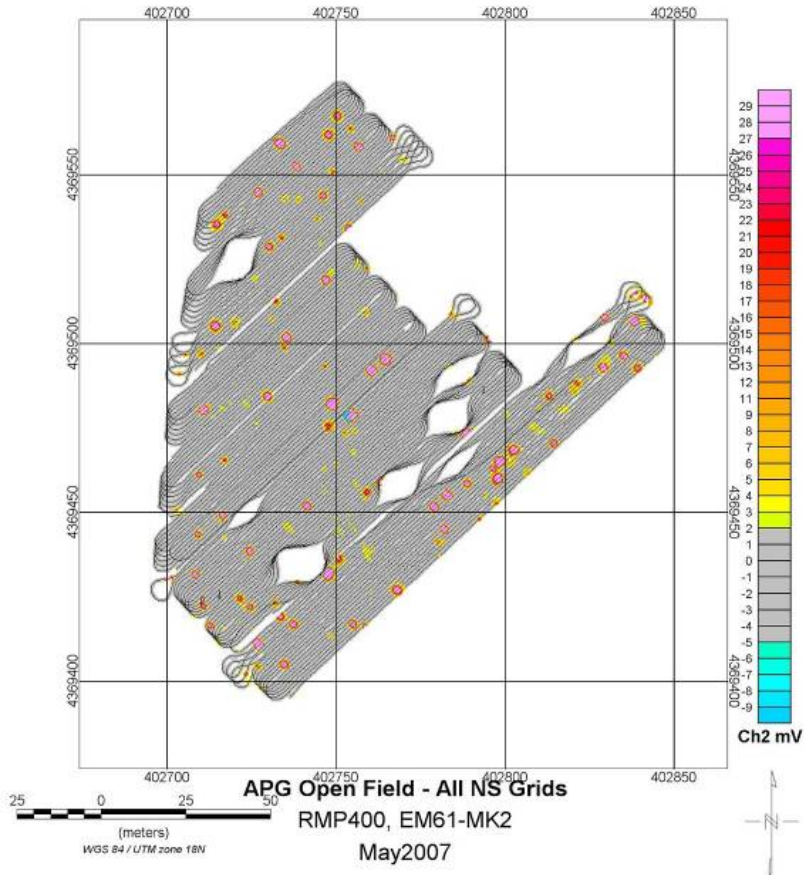
Figure 4-6: Open field survey-Area showing all obstacle avoidance/ water hazard data gaps.
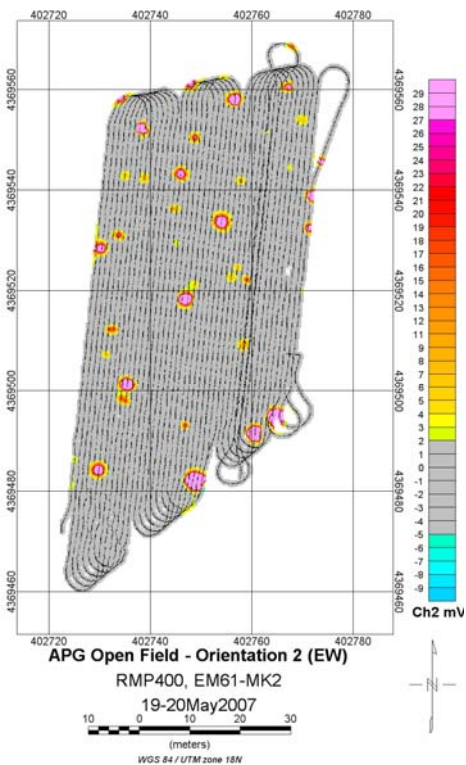
Figure 4-7: Grid 5-Survey grid without obstacles.

Table 4-7 Open Field Evaluation Summary Table 1

Open Field — Note: using obstacle polygons to exclude area from footprint coverage calculation, but actual missing data (gaps) are larger than the poly's due to having to avoid them, so still shows up as less % coverage

Date	Platform	Grid	(ucelatency, ucedrift) Processing Steps	4 or D?	(ucewindowstats) Bkg Standard Deviation	(ucevelocity) Velocity (mph)	Velocity (mph) [manual calc from one line]	(ucedatasep) Sample Separation (% points >0.2m)	
5/16/07	RMP, hitch angle sensor	1	drift corr, 0.3 latency	4	Ch2Lev: 0.47, Ch3Lev: 0.38	SD: 0.57, mean: 1.86	1.74	0%, SD: 0.04; mean: 0.08	
5/21/07	RMP	1	drift corr, 0.4 latency	4	Ch2Lev: 0.44, Ch3Lev: 0.31	SD: 0.8, mean: 1.94	1.73	0.5%, SD: 0.04; mean: 0.086	
5/20/07	RMP	2	drift corr, 0.4 latency, deleted a few bad GPS spots & interpolated (<1s of data each)	4	Ch2Lev: 0.46, Ch3Lev: 0.35	SD: 0.68, mean: 1.96	1.74	0.4%, SD: 0.031; mean: 0.087	
5/16/07	RMP, hitch angle sensor	3	1 XY flyer deleted, drift corr, 0.3 latency	4	Ch2Lev: 0.45, Ch3Lev: 0.31	SD: 0.65, mean: 1.91	1.74	0.1%, SD: 0.038; mean: 0.085	
5/16/07	RMP, hitch angle sensor	4	drift corr, 0.3 latency	4	Ch2Lev: 0.29, Ch3Lev: 0.23	SD: 0.49, mean: 1.90	1.74	0.0%, SD: 0.02; mean: 0.085	
5/17/07	RMP	4	drift corr, 0.3 latency	4	Ch2Lev: 0.49, Ch3Lev: 0.31	SD: 0.49, mean: 1.90	1.74	0.0%, SD: 0.02; mean: 0.085	
5/18/07	RMP	4	drift corr, 0.4 latency	4	Ch2Lev: 0.46, Ch3Lev: 0.28	SD: 0.68, mean: 1.95	1.73	0.3%, SD: 0.03; mean: 0.087	
5/19/07	RMP	5, part1	drift corr, 0.4 latency	4	Ch2Lev: 0.59, Ch3Lev: 0.33	SD: 0.59, mean: 1.87	1.74	0.2%, SD: 0.03; mean: 0.083	

5/20/07	RMP	5, part2	drift corr, 0.4 latency	4	Ch2Lev: 0.51, Ch3Lev: 0.26	SD: 0.55, mean: 1.77	1.75	0.1%, SD: 0.025; mean: 0.08	
5/20/07	RMP	5, part3	drift corr, 0.4 latency	4	Ch2Lev: 0.41, Ch3Lev: 0.25	SD: 0.54, mean: 1.80	1.75	0.1%, SD: 0.025; mean: 0.08	
5/19-20/07	RMP	5 (all merged)	merged 3 parts gdb's						
5/18/07	Man Portable	4	drift corr, 0.4 latency	D	Ch2Lev: 0.62, Ch3Lev: 0.73	SD: 1.79, mean: 3.09	2.93	31%, SD: 0.09; mean: 0.15	
5/18/07	XT	4, trial 1 (partial)	drift corr, 0.4 latency	D	Ch2Lev: 0.49, Ch3Lev: 0.35	SD: 1.75, mean: 1.67 (lots of zero's averaged in)	3.09	12.3%, SD: 0.09; mean: 0.082	
5/18/07	XT	4, trial 1 (partial)	re-import from *r61 file, get quality fix 1 & 5 data that was clipped out from xyz export						
5/18/07	XT	4, trial 2	re-import from *.r61 file to get all data: drift corr, 0.3 latency, deleted positioning flyers & interpolated (4 places, 1-3 sec each), deleted '0' lat/longs where quality changes from 5 to 1	D	Ch2Lev: 1.4, Ch3Lev: 1.04 (used a slightly smaller background statistics polygon to avoid large anomaly)	SD: 2.48, mean: 3.38	3.32	38.6%, SD: 0.13; mean: 0.17	

5/21/07	XT	4	xyz import (doesn't include most bad GPS-quality flags, so some gaps in coverage where GPS was bad); deleted some remaining GPS flyers and interpolated positions along obvious path; drift corr, 0.4 latency,	4	Ch2Lev: 1.2, Ch3Lev: 0.95	SD: 1.73, mean: 3.45	3.92	38.1%, SD: 0.10; mean: 0.17	

Notes:
1. Column 5 specifies if 4 gates of the EM-61 bottom coil or 3 from the bottom and the top for a differential was used in evaluations.
2. Column 6 specifies the background standard deviations
3. The velocities in column 7 and 8 differ due to how they were calculated. Column 7 uses all points along the line by GEOSOFT (generally at .08 m spacing). The velocity in column 8 is calculated by using the end points of the straight lines within the grid.

Table 4-8 Open Field Evaluation Summary Table 2

Open Field Note: using obstacle polygons to exclude area from footprint coverage calculation, but actual missing data (gaps) are larger than the poly's due to having to avoid them, so still shows up as less % coverage

(ucefootprintcov)

Date	Platform	Grid	Total area inside grid [m^2]	Area of obstacles inside grid [m2]	Area Covered (inside grid) [m^2]	Footprint Coverage (% at 1m) - excluding obstacles	Gaps [m^2] - excluding obstacles	Total Area Covered (including turns) [m^2]	Footprint Coverage (% at 1.2m) in subset of area with full coverage, to check lane spacing	Collection Time (min:sec)	Total Time inc stops (min:sec)
5/16/07	RMP, hitch angle sensor	1	3045.05	0.00	2409.36	79.12%	635.69	2673	98.65%	72:48	79:36
5/21/07	RMP	1	3045.05	71.27	2488.99	83.70%	484.79	2855.25	98.59%	78:27	
5/20/07	RMP	2	3060.00	219.45	2373.25	83.55%	467.30	2913.21	98.87%	82:47	
5/16/07	RMP, hitch angle sensor	3	3123.64	0.00	2648.64	84.79%	475.00	3015.28	99.01%	81:07	83:29
5/16/07	RMP, hitch angle sensor	4	2032.02	69.90	1107.98	56.47%	854.14	1643.61	98.72%	47:30	53:15
5/17/07	RMP	4	2032.02	69.90	1599.81	81.53%	362.31	2294.96	99.07%	64:28	65:13
5/18/07	RMP	4	2032.02	69.90	1710.72	87.19%	251.40	2420.27	99.80%	65:31	
5/19/07	RMP	5, part1					0.00	2462.41	99.99%	56:54	
5/20/07	RMP	5, part2					0.00	256.3	99.99%	5:42	
5/20/07	RMP	5, part3					0.00	1070.88	100.00%	26:21	
5/19-20/07	RMP	5 (all merged)	2863.15	0.00	2807.96	98.07%	55.19	3615.51			
5/18/07	Man Portable	4	2032.02	0.00	1693.73	83.35%	338.29	1977.27	94.02%	32:03	

5/18/07	XT	4, trial 1 (partial)	2032.02	69.90	180.23	9.19%	1781.89	245.01	75.51% (wide lane spacing for 1 of 3 lines)	6:57	9:20
5/18/07	XT	4, trial 1 (partial)									
5/18/07	XT	4, trial 2	2032.02	69.90	1493.41	76.11%	468.71	2054.59	88.68% (taken from area with best coverage)	34:58	39:0
5/21/07	XT	4	2032.02	69.90	1448.77	73.84%	513.35	1829.56	88.41% (poor lane spacing, doesn't include gaps)	29:15 (inc ~2min of time gaps)	32:11 (including all bad GPS - *.r61 import)

5. Cost Assessment

5.1 Cost Reporting
Costs are related to productivity and required man power for the various towed methods. They are tabulated as described under Cost Comparison.

5.2 Cost Analysis

Cost Comparison

Productivity and cost is compared for the RMP 400 robotic towing method as benchmarked to the man towed methodology. For this demonstration we restricted the robot velocity to 1.75 mph not based upon robot limitations but to minimize shock damage to our unhardened prototype components due to the rough ground surface. We plan to harden these components and double the speed for future efforts. Manned surveys averaged 2.7 mph. This resulted in an average productivity for continuous operation of .56 acre/hr for the robot and .85 acre/hr for the man towed. Using those value alone would show manned as 50% more productive for time on grid. In reality people take work breaks and the robot does not. For this comparison we assume that the workers swap out between grids so there is no rest time. Using a 75% production rate for both would give us 6 hrs of production per day which equates to 3.36 acres per day for the robot and 5.1 for manned. A hypothetical 100 acre project would then take the robot 30 days and the man towed 20 days.

Geophysical and positioning equipment is assumed to be the same for manned and robotic towing. There are additional costs for hardware and maintenance for the robotic methodology. The prototype RMP 400 system, equipment and spares cost $33,000 with yearly maintenance and battery replacement predicted at $2800 as shown in Table 5-1 Robot Cost Basis. With a three year pay back for capital cost recovery and yearly maintenance, daily costs for the tow vehicles would be approximately $53. $100 is used in the cost work up assuming approximately a 50% usage rate.

The robots will map autonomously so they will only need one highly qualified geophysicist for operation estimated at a billed rate of $100 per hour or $800 per day. Manned equipment typically requires one geophysicist and two technicians to establish and maintain line and track. Cost comparison will use labor costs estimated at $90 for the geophysicist and $50 each for the technicians for a cost of $1520 per day. Costs of lodging and travel will be assumed to be the same although the robot effort would require less. Mobilization and demobilization is also assumed to be equal. Based upon the outlined production rates and man power loading, cost will be $27,000 for the Robotic effort as compared to $30,400 for manned as shown in Table 5-1 for the hypothetical 100 acre project. This results in approximately a 10% savings. That would markedly increase with the planned increase in robot velocity.

The robotic operation also provides improved data quality and accuracy from manned operations and will greatly reduce personnel risk to site hazards.

Robot Equipment Costs			Yearly Maintenance
RMP 400	$24,600		
Segway battery spares	$3,000		$1,200
Tow bars	$2,400		$1,200
stub axels	$100		
Hitch angle sensors	$300		$200
Brick computer	$1,200		
Systems batteries	$400		$200
Communication Equipment	$1,000		
Total	$33,000		$2,800

Table 5-1 Robot Cost Basis

Hypothetical 100 acre project				
	Daily cost		work days	Cost
Robot	$100		30	$3,000
Robot Geophysicist	$800		30	$24,000
			Robot Total	$27,000
Manned Technical labor	$1,520		20	$30,400
			Man towed Total	$30,400

Table 5-2 100 Acre Survey Cost

Cost Basis
Costs of the system are as shown in Table 5-1.

Cost Drivers
The robot operations did not require additional time for setup or for data processing. The equipment was carried to the site assembled and the robot specific data processing was all automated to product output files read for GEOSOFT analysis. Grid path planning only takes a few minutes to enter corner coordinates, direction of travel and obstruction locations. The path file is automatically generated.

Life Cycle Costs
Life-cycle costs include acquisition, operations, and maintenance.   A three-year system life was assumed with maintenance and operation as described under Cost Comparison. No other costs are incurred.

6. Implementation Issues

6.1 Environmental Checklist

There are no permits or regulations that impact this technology.

6.2 Other Regulatory Issues

This technology is not primarily driven by regulatory issues, but instead by a desire for higher data quality, greater production, reduced cost and reduced risk. Information about this technology will be disseminated via technology conferences (such as the UXO Forum & SERDP/ESTCP Symposium), by direct contact with appropriate government representatives working in UXO issues, and by direct contact with contractors who support government activities.

6.3 End-User Issues

CEHNC is the lead on this project because of their pressing need for better technology for DGM and UXO operations. CEHNC is prepared to advocate this technology into the user community if it is shown to meet the objectives defined herein.

7. References

Two papers have been published and presented at international conferences based on work done in the development of the autonomous geophysical mapping system. The first, titled Effects of Sensor Placement and Errors on Path Following Control of a Mobile Robot-Trailer System, was presented in an oral session at the 2007 American Controls Conference in New York on July 12, 2007 and was published in the proceedings of that conference. The second, titled Linear Analysis of Trailer Lateral Error with Sensor Noise for a Mobile Robot-Trailer System was presented in a poster session at the 2007 IEEE International Symposium on Industrial Electronics in Vigo, Spain on June 7, 2007 and also appears in the proceedings of that conference. The project also provided the basis for David Hodo's Master of Science thesis, Development of an Autonomous Mobile Robot-Trailer System for UXO, It can be downloaded from http://graduate.auburn.edu/auetd/, search by author- Hodo.

D. W. Hodo, J. Y. Hung, D. M. Bevly, and S. Millhouse, "Linear analysis of trailer lateral error with sensor noise for a mobile robot-trailer system," in Proceedings of the 2007 IEEE International Symposium on Industrial Electronics, Vigo, Spain, IEEE June 2007.

D. W. Hodo, J. Y. Hung, D. M. Bevly, and S. Millhouse, "Effects of sensor placement and errors on path following control of a mobile robot-trailer system," in Proceedings of the 2007 American Control Conference, New York City, July 2007.

8. Points of Contact

Point of Contact	Address	Phone/Fax/Email	Role in Project
Scott Millhouse, PE	U.S. Army Corps of Engineers, Engineering & Support Center- Huntsville 4820 University Square Huntsville, Alabama 35816-1822	Ph: 256-895-1607 Fax: 256-895-1737 scott.d.millhouse@ hnd01.usace.army.mil	Principle Investigator

Signature of Project Lead

D. Scott Millhouse   *August 22, 2007*

Scott Millhouse, PE   Date

Appendix A: Analytical Methods Supporting the Experimental Design

Not required.

Appendix B: Data Storage and Archiving Procedures

A copy of the data is included with this report as archived on CD.

Appendix C: APG Demonstration – Geophysical Representations and Dig Lists

Calibration Grid

The APG Calibration Grid, containing 128 known seed items, was surveyed multiple times using the RMP 400 robot, the Segway XT and as man towed with the EM-61 MK2. It was also surveyed one time with the RMP 400 robot towing a dual array of Geometrics G-858 total field cesium vapor magnetometers. A data set (man-portable EM61 MK2 data collected in May 2004 by CEHNC geophysicists, with a Novatel DGPS) was used as a baseline for target selection accuracy. Each target list was compared against the known seed items with any targets selected outside the seed area (including the boundary shot puts) were removed from the list.
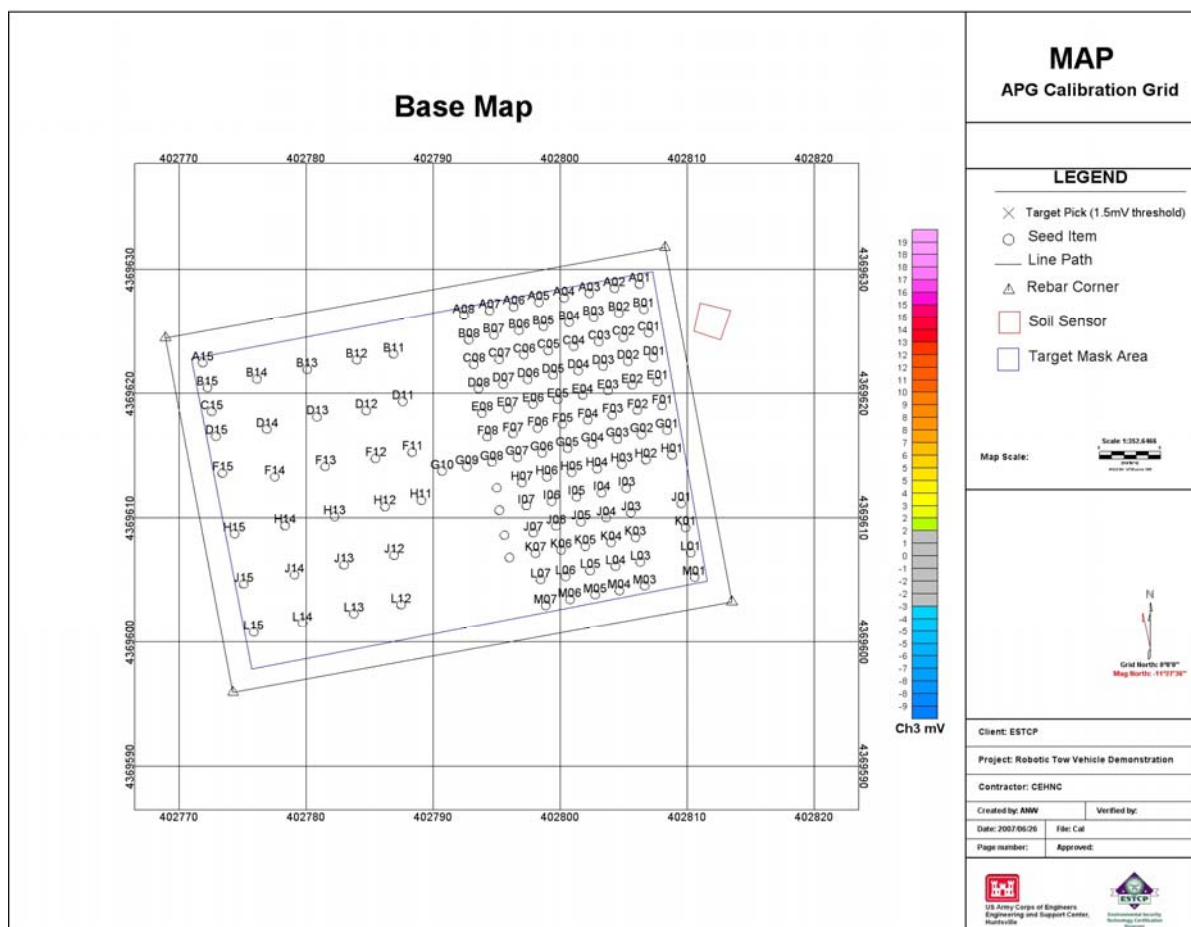
Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

Baseline: Man-Portable EM61MK2, May 2004, Grid NS
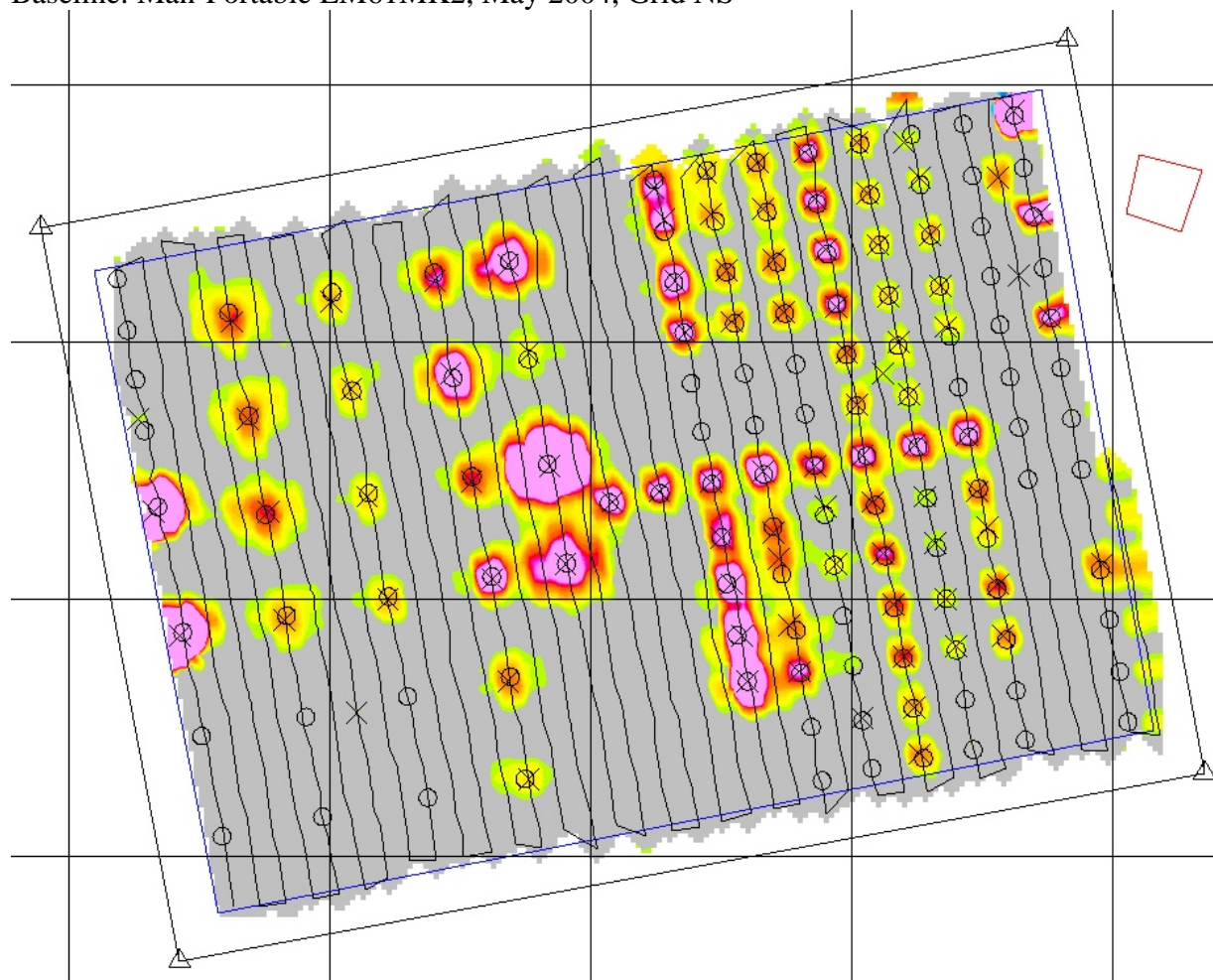
Baseline Dig Sheet:

89 of 128 seed items found
2 extra picks
Avg offset dist: 0.20m

Target_ID	X	Y	ch3(mV)	SeedMatched	SeedX	SeedY	Offset
1	402773.20	4369613.40	770.8	F15	402773.39	4369613.59	0.27
2	402774.20	4369608.60	611.2	H15	402774.35	4369608.71	0.19
3	402788.40	4369615.20	327.3	F11	402788.33	4369615.26	0.09
4	402806.20	4369629.00	254.7	A01	402806.23	4369628.81	0.19
5	402796.00	4369606.80	90.9	K08	402796.00	4369606.80	0.00
6	402795.80	4369608.60	50.6	J08	402795.60	4369608.60	0.20
7	402786.20	4369610.80	46.4	H12	402786.20	4369610.89	0.09
8	402784.60	4369618.80	44.8	D12	402784.71	4369618.61	0.22
9	402796.60	4369615.00	37.6	G07	402796.62	4369614.85	0.15
10	402793.20	4369622.40	37.3	C08	402793.19	4369622.32	0.08
11	402789.00	4369611.40	35.7	H11	402789.06	4369611.40	0.06
12	402786.80	4369623.00	35.0	B11	402786.88	4369623.16	0.18
13	402807.20	4369625.00	31.8	C01	402806.96	4369624.87	0.27
14	402795.40	4369610.60	30.9	I08	402795.20	4369610.60	0.20

15	402790.80	4369613.80	30.2	G10	402790.70	4369613.75	0.11
16	402792.80	4369624.80	28.6	B08	402792.80	4369624.31	0.49
17	402804.40	4369616.40	28.4	G03	402804.49	4369616.31	0.13
18	402802.40	4369616.00	28.2	G04	402802.54	4369615.92	0.16
19	402793.60	4369620.40	27.5	D08	402793.56	4369620.36	0.06
20	402807.60	4369621.00	26.5	E01	402807.66	4369620.93	0.09
21	402799.00	4369623.60	25.9	C05	402799.05	4369623.43	0.18
22	402792.60	4369614.20	24.7	G09	402792.64	4369614.11	0.10
23	402798.60	4369625.60	23.7	B05	402798.67	4369625.38	0.23
24	402800.40	4369615.60	23.6	G05	402800.57	4369615.58	0.17
25	402794.60	4369614.60	23.6	G08	402794.62	4369614.48	0.12
26	402798.20	4369627.40	23.2	A05	402798.32	4369627.35	0.13
27	402792.40	4369626.00	21.1	A08	402792.43	4369626.30	0.30
28	402799.40	4369621.40	20.4	D05	402799.43	4369621.48	0.09
29	402798.60	4369615.20	19.6	G06	402798.57	4369615.20	0.03
30	402798.00	4369607.20	19.6	K07	402798.05	4369607.13	0.09
31	402795.00	4369612.40	19.3	H08	402795.00	4369612.40	0.00
32	402801.20	4369611.80	18.3	I05	402801.27	4369611.67	0.15
33	402784.00	4369622.40	17.3	B12	402783.97	4369622.69	0.29
34	402802.00	4369607.80	15.3	K05	402801.97	4369607.70	0.10
35	402805.60	4369610.60	14.9	J03	402805.56	4369610.40	0.20
36	402777.60	4369613.40	14.8	F14	402777.51	4369613.29	0.14
37	402785.40	4369614.60	14.5	F12	402785.44	4369614.77	0.17
38	402776.20	4369620.80	13.3	B14	402776.10	4369621.14	0.35
39	402800.80	4369613.80	13.1	H05	402800.90	4369613.66	0.17
40	402797.00	4369612.60	12.4	H07	402796.98	4369612.83	0.23
41	402801.60	4369609.80	12.3	J05	402801.62	4369609.66	0.14
42	402797.20	4369611.60	12.2	I07	402797.32	4369610.97	0.64
43	402799.80	4369619.60	11.3	E05	402799.80	4369619.50	0.10
44	402776.80	4369617.00	11.1	D14	402776.88	4369617.12	0.14
45	402797.40	4369621.20	11.0	D06	402797.44	4369621.11	0.10
46	402795.20	4369622.80	10.6	C07	402795.19	4369622.72	0.08
47	402797.60	4369609.00	10.1	J07	402797.87	4369608.79	0.34
48	402804.80	4369614.20	9.9	H03	402804.86	4369614.29	0.11
49	402809.60	4369611.40	9.8	J01	402809.53	4369611.13	0.28
50	402797.00	4369623.20	9.7	C06	402797.14	4369623.09	0.18
51	402786.80	4369606.80	9.5	J12	402786.91	4369606.98	0.21
52	402805.80	4369608.60	9.3	K03	402805.92	4369608.42	0.22
53	402805.60	4369626.40	9.2	B02	402804.62	4369626.47	0.98
54	402802.60	4369604.00	9.0	M05	402802.76	4369603.81	0.25
55	402795.40	4369620.80	8.6	D07	402795.50	4369620.73	0.12
56	402794.60	4369625.00	8.4	B07	402794.78	4369624.69	0.36
57	402796.40	4369627.00	8.3	A06	402796.33	4369626.99	0.07
58	402803.00	4369624.20	8.1	C03	402803.04	4369624.15	0.06
59	402802.40	4369605.80	7.9	L05	402802.35	4369605.75	0.07
60	402800.20	4369617.60	7.8	F05	402800.16	4369617.52	0.09
61	402800.20	4369627.80	7.6	A04	402800.30	4369627.71	0.13
62	402778.20	4369609.20	7.6	H14	402778.33	4369609.36	0.21
63	402800.60	4369625.80	7.6	B04	402800.70	4369625.73	0.12
64	402782.20	4369610.00	7.3	H13	402782.23	4369610.10	0.10
65	402796.60	4369625.20	7.2	B06	402796.75	4369625.06	0.21
66	402805.20	4369612.80	6.8	I03	402805.20	4369612.37	0.43
67	402794.40	4369626.60	6.3	A07	402794.43	4369626.67	0.08

68	402780.00	4369621.60	6.3	B13	402780.07	4369621.92	0.33
69	402803.40	4369622.20	6.1	D03	402803.37	4369622.18	0.04
70	402780.80	4369618.20	6.1	D13	402780.84	4369618.10	0.11
71	402801.40	4369621.80	5.9	D04	402801.41	4369621.82	0.02
72	402801.00	4369623.80	5.7	C04	402801.06	4369623.77	0.07
73	402787.60	4369603.00	5.1	L12	402787.47	4369603.01	0.13
74	402781.40	4369614.00	5.0	F13	402781.48	4369614.12	0.14
75	402802.20	4369618.00	4.7	F04	402802.17	4369617.87	0.13
76	402803.60	4369620.60	4.4	E03	402803.77	4369620.22	0.42
77	402804.00	4369608.20	4.4	K04	402804.00	4369608.02	0.18
78	402803.60	4369610.00	4.3	J04	402803.61	4369610.01	0.01
79	402801.80	4369620.00	4.1	E04	402801.77	4369619.85	0.15
80	402802.60	4369626.40	4.1	B03	402802.63	4369626.12	0.28
81	402799.40	4369611.40	3.7	I06	402799.31	4369611.32	0.12
82	402787.60	4369619.60	3.1	D11	402787.59	4369619.34	0.26
83	402802.00	4369627.80	2.9	A03	402802.29	4369628.07	0.40
84	402799.00	4369613.60	2.9	H06	402798.95	4369613.28	0.32
85	402801.20	4369618.80	2.6				
86	402802.80	4369614.00	2.6	H04	402802.90	4369613.93	0.12
87	402803.20	4369612.20	2.3	I04	402803.26	4369612.00	0.21
88	402772.60	4369617.00	2.0	D15	402772.88	4369616.54	0.54
89	402781.00	4369605.60	1.7				
90	402806.40	4369622.60	1.6	D01	402807.35	4369622.88	0.99
91	402800.40	4369605.40	1.6	L06	402800.41	4369605.27	0.13

RMP400 Robot-towed EM61MK2 with Hitch Angle Sensor, 5/15/07, Grid NS, Offset from items

Notes: Missing Eastern last line & part of next line.
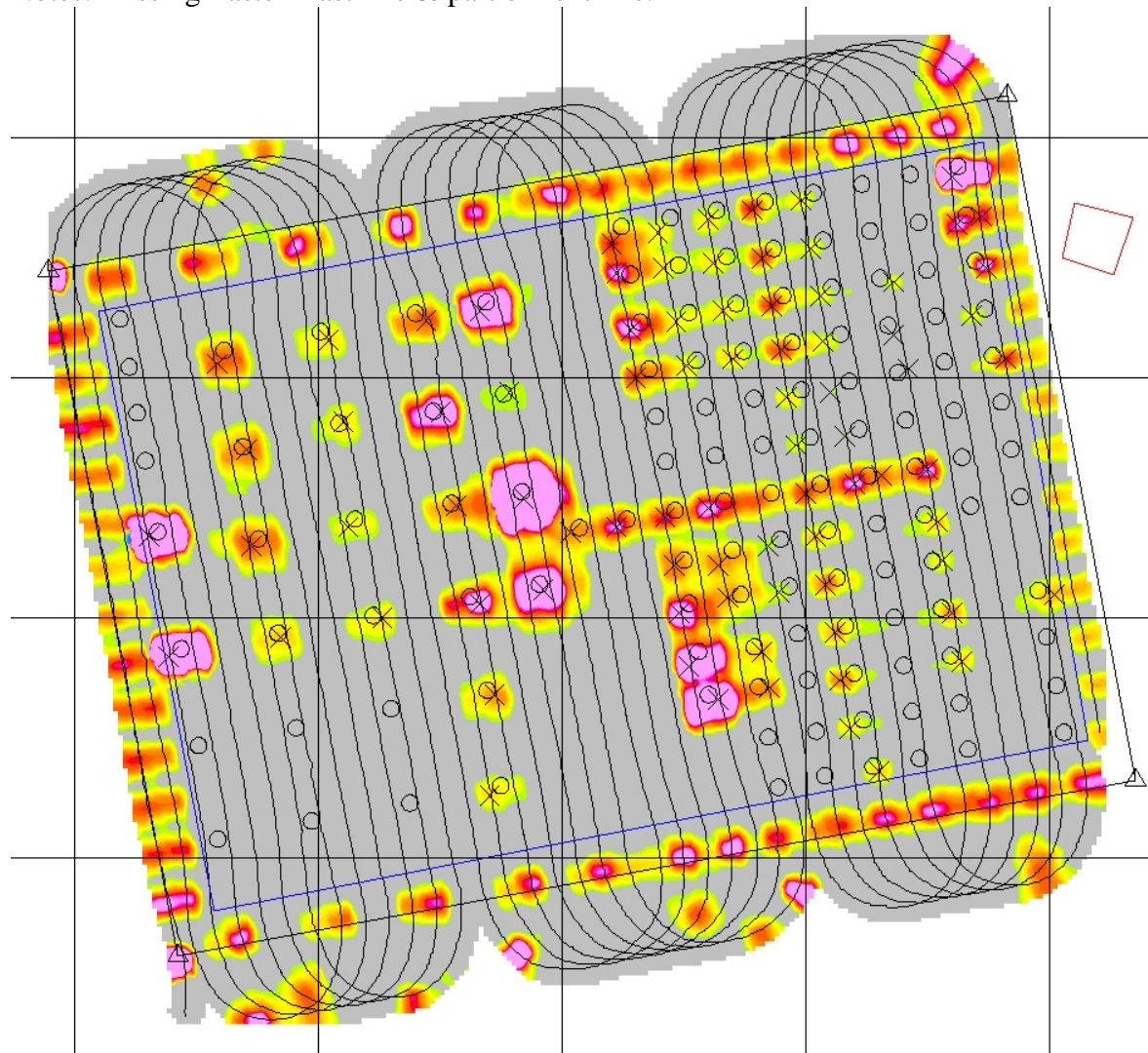
Digsheet:

80 of 128 seed items found
2 extra picks
Avg offset dist: 0.53m

Target_ID	x	y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.00	4369613.40	402.0	F15	402773.39	4369613.59	0.43
2	402788.40	4369615.00	335.3	F11	402788.33	4369615.26	0.27
3	402773.80	4369608.40	304.3	H15	402774.35	4369608.71	0.63
4	402806.00	4369628.40	135.3	A01	402806.23	4369628.81	0.47
5	402796.40	4369606.60	58.7	K08	402796.00	4369606.80	0.45
6	402795.20	4369608.00	40.5	J08	402795.60	4369608.60	0.72
7	402789.20	4369611.20	36.6	H11	402789.06	4369611.40	0.24
8	402786.60	4369622.80	35.8	B11	402786.88	4369623.16	0.46
9	402785.00	4369618.60	32.0	D12	402784.71	4369618.61	0.29
10	402786.60	4369610.60	27.7	H12	402786.20	4369610.89	0.49

11	402794.80	4369610.20	23.9	I08	402795.20	4369610.60	0.57
12	402792.80	4369622.00	23.7	C08	402793.19	4369622.32	0.50
13	402807.40	4369624.60	21.2	C01	402806.96	4369624.87	0.52
14	402802.00	4369615.60	20.7				
15	402796.00	4369614.60	20.0	G07	402796.62	4369614.85	0.67
16	402792.20	4369624.40	19.9	B08	402792.80	4369624.31	0.61
17	402792.20	4369613.80	19.6	G09	402792.64	4369614.11	0.54
18	402806.20	4369626.40	19.5	B01	402806.58	4369626.78	0.54
19	402805.00	4369616.20	19.0	G03	402804.49	4369616.31	0.52
20	402794.20	4369614.20	16.6	G08	402794.62	4369614.48	0.50
21	402807.20	4369626.75	16.0				
22	402797.80	4369627.00	14.8	A05	402798.32	4369627.35	0.63
23	402808.20	4369620.80	14.6	E01	402807.66	4369620.93	0.56
24	402792.00	4369625.60	14.6	A08	402792.43	4369626.30	0.82
25	402798.60	4369623.00	14.5	C05	402799.05	4369623.43	0.62
26	402800.00	4369615.20	14.0	G05	402800.57	4369615.58	0.69
27	402793.00	4369620.00	13.9	D08	402793.56	4369620.36	0.67
28	402798.20	4369625.00	13.6	B05	402798.67	4369625.38	0.60
29	402799.00	4369621.20	12.6	D05	402799.43	4369621.48	0.51
30	402775.80	4369620.60	12.2	B14	402776.10	4369621.14	0.62
31	402777.20	4369613.00	12.1	F14	402777.51	4369613.29	0.42
32	402784.40	4369622.40	11.6	B12	402783.97	4369622.69	0.52
33	402800.80	4369611.40	11.2	I05	402801.27	4369611.67	0.54
34	402803.09	4369615.95	10.2	G04	402802.54	4369615.92	0.55
35	402777.00	4369617.00	10.1	D14	402776.88	4369617.12	0.17
36	402785.64	4369614.66	9.9	F12	402785.44	4369614.77	0.23
37	402801.40	4369607.40	9.3	K05	402801.97	4369607.70	0.64
38	402794.60	4369612.20	9.2	H08	402795.00	4369612.40	0.45
39	402796.40	4369612.20	8.8	H07	402796.98	4369612.83	0.86
40	402798.47	4369607.10	8.7	K07	402798.05	4369607.13	0.42
41	402801.20	4369609.40	8.5	J05	402801.62	4369609.66	0.49
42	402787.20	4369606.80	8.2	J12	402786.91	4369606.98	0.34
43	402806.00	4369610.20	8.2	J03	402805.56	4369610.40	0.48
44	402790.32	4369613.55	8.0	G10	402790.70	4369613.75	0.43
45	402796.79	4369610.85	7.9	I07	402797.32	4369610.97	0.54
46	402798.20	4369608.60	7.2	J07	402797.87	4369608.79	0.38
47	402810.20	4369611.00	6.6	J01	402809.53	4369611.13	0.68
48	402800.40	4369613.40	6.5	H05	402800.90	4369613.66	0.56
49	402805.40	4369614.00	6.3	H03	402804.86	4369614.29	0.61
50	402797.00	4369620.80	6.0	D06	402797.44	4369621.11	0.54
51	402778.40	4369609.20	6.0	H14	402778.33	4369609.36	0.17
52	402803.00	4369603.60	5.8	M05	402802.76	4369603.81	0.32
53	402806.40	4369608.20	5.7	K03	402805.92	4369608.42	0.53
54	402782.60	4369610.00	5.6	H13	402782.23	4369610.10	0.38
55	402796.00	4369626.60	5.4	A06	402796.33	4369626.99	0.51
56	402787.00	4369602.60	5.3	L12	402787.47	4369603.01	0.62
57	402796.60	4369622.80	5.3	C06	402797.14	4369623.09	0.61
58	402794.14	4369624.58	5.0	B07	402794.78	4369624.69	0.65
59	402781.00	4369618.20	4.9	D13	402780.84	4369618.10	0.19
60	402780.40	4369621.60	4.9	B13	402780.07	4369621.92	0.46
61	402801.80	4369605.40	4.7	L05	402802.35	4369605.75	0.65
62	402796.20	4369624.80	4.6	B06	402796.75	4369625.06	0.61
63	402799.80	4369627.40	4.6	A04	402800.30	4369627.71	0.59

64	402799.20	4369619.20	4.5	E05	402799.80	4369619.50	0.67
65	402795.06	4369620.53	4.4	D07	402795.50	4369620.73	0.48
66	402794.66	4369622.35	4.2	C07	402795.19	4369622.72	0.65
67	402803.60	4369624.00	4.1	C03	402803.04	4369624.15	0.58
68	402800.60	4369623.40	3.9	C04	402801.06	4369623.77	0.59
69	402793.90	4369626.04	3.8	A07	402794.43	4369626.67	0.82
70	402800.20	4369625.40	3.6	B04	402800.70	4369625.73	0.60
71	402805.60	4369612.40	3.6	I03	402805.20	4369612.37	0.40
72	402806.80	4369622.60	3.5	D01	402807.35	4369622.88	0.62
73	402781.20	4369613.80	3.3	F13	402781.48	4369614.12	0.43
74	402800.67	4369621.53	2.9	D04	402801.41	4369621.82	0.80
75	402799.60	4369617.20	2.9	F05	402800.16	4369617.52	0.64
76	402798.87	4369611.09	2.5	I06	402799.31	4369611.32	0.49
77	402787.80	4369619.40	2.4	D11	402787.59	4369619.34	0.22
78	402798.41	4369613.02	2.0	H06	402798.95	4369613.28	0.60
79	402801.60	4369617.60	1.8	F04	402802.17	4369617.87	0.63
80	402801.00	4369619.40	1.6	E04	402801.77	4369619.85	0.89
81	402804.20	4369620.40	1.5	E03	402803.77	4369620.22	0.47
82	402803.60	4369621.80	1.5	D03	402803.37	4369622.18	0.44

RMP400 Robot-towed EM61MK2 with Hitch Angle Sensor, 5/15/07, True NS,
Notes: SE corner gaps from avoiding soil sensor; ~16s time jump (no readings) but outside of
grid.
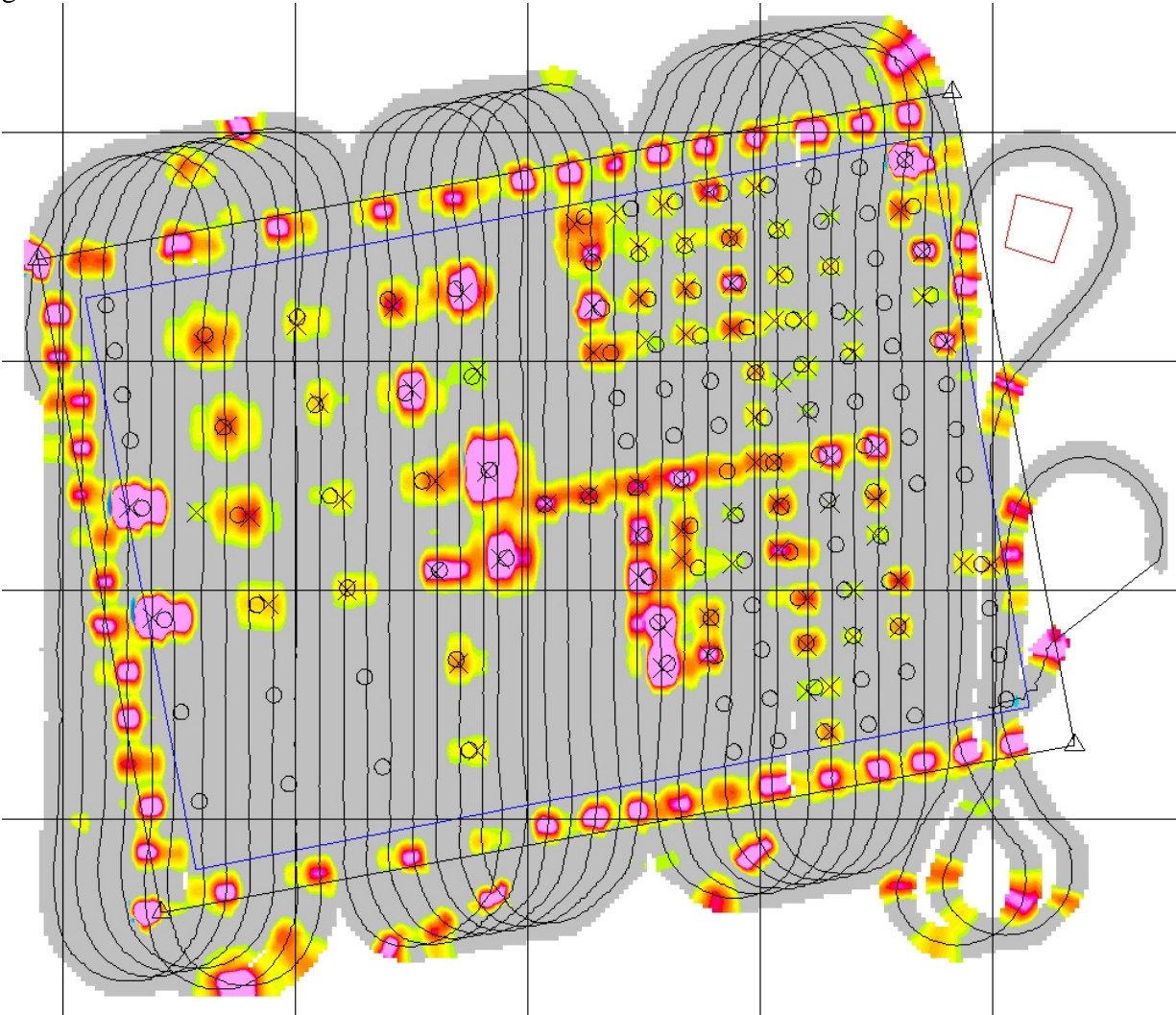
Dig Sheet:

84 of 128 seed items found
6 extra picks
Avg offset dist: 0.33m

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402772.80	4369613.60	517.1	F15	402773.39	4369613.59	0.59
2	402773.80	4369608.80	509.0	H15	402774.35	4369608.71	0.56
3	402788.20	4369615.20	318.9	F11	402788.33	4369615.26	0.14
4	402806.20	4369628.80	215.4	A01	402806.23	4369628.81	0.03
5	402795.80	4369606.60	90.5	K08	402796.00	4369606.80	0.28
6	402785.00	4369618.80	47.4	D12	402784.71	4369618.61	0.35
7	402795.80	4369608.40	42.9	J08	402795.60	4369608.60	0.28
8	402787.20	4369623.00	42.7	B11	402786.88	4369623.16	0.36
9	402788.80	4369611.40	37.5	H11	402789.06	4369611.40	0.26
10	402792.80	4369622.40	35.8	C08	402793.19	4369622.32	0.40
11	402808.00	4369620.80	29.9	E01	402807.66	4369620.93	0.36

12	402805.00	4369616.20	28.8	G03	402804.49	4369616.31	0.52
13	402807.00	4369624.80	27.2	C01	402806.96	4369624.87	0.08
14	402786.00	4369610.80	26.5	H12	402786.20	4369610.89	0.22
15	402794.80	4369610.60	26.2	I08	402795.20	4369610.60	0.40
16	402803.00	4369615.80	25.4	G04	402802.54	4369615.92	0.48
17	402798.80	4369623.40	23.9	C05	402799.05	4369623.43	0.25
18	402796.60	4369614.80	22.5	G07	402796.62	4369614.85	0.05
19	402797.80	4369627.40	20.5	A05	402798.32	4369627.35	0.52
20	402797.80	4369607.20	20.0	K07	402798.05	4369607.13	0.26
21	402792.60	4369624.80	18.5	B08	402792.80	4369624.31	0.53
22	402794.80	4369612.40	18.4	H08	402795.00	4369612.40	0.20
23	402790.80	4369613.80	18.4	G10	402790.70	4369613.75	0.11
24	402800.80	4369611.80	17.0	I05	402801.27	4369611.67	0.49
25	402794.80	4369614.60	16.0	G08	402794.62	4369614.48	0.22
26	402784.20	4369622.40	15.6	B12	402783.97	4369622.69	0.37
27	402792.60	4369614.20	14.9	G09	402792.64	4369614.11	0.10
28	402806.00	4369610.40	14.8	J03	402805.56	4369610.40	0.44
29	402802.00	4369609.60	13.7	J05	402801.62	4369609.66	0.38
30	402800.80	4369613.80	13.5	H05	402800.90	4369613.66	0.17
31	402778.00	4369613.20	13.5	F14	402777.51	4369613.29	0.50
32	402798.80	4369621.40	13.4	D05	402799.43	4369621.48	0.64
33	402776.00	4369620.80	13.4	B14	402776.10	4369621.14	0.35
34	402796.60	4369612.60	13.0	H07	402796.98	4369612.83	0.44
35	402806.00	4369626.60	13.0	B01	402806.58	4369626.78	0.61
36	402792.80	4369620.40	12.8	D08	402793.56	4369620.36	0.76
37	402777.00	4369617.20	12.5	D14	402776.88	4369617.12	0.14
38	402802.00	4369607.60	12.1	K05	402801.97	4369607.70	0.10
39	402792.00	4369626.00	12.0	A08	402792.43	4369626.30	0.52
40	402798.80	4369625.40	11.6	B05	402798.67	4369625.38	0.13
41	402799.80	4369615.60	11.4				
42	402786.00	4369614.80	11.3	F12	402785.44	4369614.77	0.56
43	402800.60	4369615.60	11.1	G05	402800.57	4369615.58	0.04
44	402796.60	4369611.40	11.0	I07	402797.32	4369610.97	0.84
45	402805.00	4369614.00	10.7	H03	402804.86	4369614.29	0.32
46	402797.80	4369608.80	9.9	J07	402797.87	4369608.79	0.07
47	402794.80	4369622.80	9.8	C07	402795.19	4369622.72	0.40
48	402796.80	4369623.20	9.4	C06	402797.14	4369623.09	0.36
49	402803.00	4369603.80	8.9	M05	402802.76	4369603.81	0.24
50	402806.00	4369608.40	8.4	K03	402805.92	4369608.42	0.08
51	402787.00	4369606.80	8.1	J12	402786.91	4369606.98	0.20
52	402796.80	4369621.20	7.4	D06	402797.44	4369621.11	0.65
53	402809.89	4369611.11	7.3	J01	402809.53	4369611.13	0.36
54	402799.80	4369619.60	7.1	E05	402799.80	4369619.50	0.10
55	402799.80	4369627.60	6.2	A04	402800.30	4369627.71	0.51
56	402781.00	4369618.20	6.1	D13	402780.84	4369618.10	0.19
57	402778.80	4369609.40	6.1	H14	402778.33	4369609.36	0.47
58	402795.80	4369626.80	5.8	A06	402796.33	4369626.99	0.56
59	402803.00	4369624.20	5.5	C03	402803.04	4369624.15	0.06
60	402799.80	4369617.60	5.4	F05	402800.16	4369617.52	0.37
61	402808.72	4369611.19	5.4				
62	402800.80	4369623.80	5.3	C04	402801.06	4369623.77	0.26
63	402780.00	4369621.60	5.3	B13	402780.07	4369621.92	0.33
64	402782.20	4369610.00	5.3	H13	402782.23	4369610.10	0.10

65	402796.80	4369625.20	5.1	B06	402796.75	4369625.06	0.15
66	402794.80	4369625.00	5.0	B07	402794.78	4369624.69	0.31
67	402782.00	4369614.00	4.5	F13	402781.48	4369614.12	0.53
68	402803.00	4369605.80	4.5				
69	402787.80	4369603.00	4.4	L12	402787.47	4369603.01	0.33
70	402793.75	4369626.45	4.2	A07	402794.43	4369626.67	0.71
71	402800.60	4369621.80	4.1				
72	402800.80	4369625.80	3.8	B04	402800.70	4369625.73	0.12
73	402801.80	4369621.80	3.7	D04	402801.41	4369621.82	0.39
74	402804.00	4369620.40	3.7	E03	402803.77	4369620.22	0.29
75	402804.00	4369608.00	3.5	K04	402804.00	4369608.02	0.02
76	402807.00	4369622.80	3.4	D01	402807.35	4369622.88	0.36
77	402802.00	4369619.80	3.3	E04	402801.77	4369619.85	0.24
78	402804.00	4369610.00	2.9	J04	402803.61	4369610.01	0.39
79	402775.73	4369613.40	2.9				
80	402795.08	4369620.93	2.8	D07	402795.50	4369620.73	0.47
81	402804.00	4369622.00	2.8	D03	402803.37	4369622.18	0.66
82	402805.00	4369612.40	2.7	I03	402805.20	4369612.37	0.20
83	402798.79	4369611.19	2.7	I06	402799.31	4369611.32	0.54
84	402802.00	4369605.60	2.6	L05	402802.35	4369605.75	0.38
85	402798.80	4369613.40	2.5	H06	402798.95	4369613.28	0.19
86	402803.00	4369626.40	2.5	B03	402802.63	4369626.12	0.46
87	402787.80	4369619.60	2.4	D11	402787.59	4369619.34	0.33
88	402800.91	4369619.12	2.0				
89	402802.00	4369617.80	1.8	F04	402802.17	4369617.87	0.18
90	402803.00	4369613.80	1.6	H04	402802.90	4369613.93	0.16

Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

RMP400 Robot-towed EM61MK2 with Hitch Angle Sensor, 5/15/07, True EW
Notes: incomplete, missing SW corner & northern area
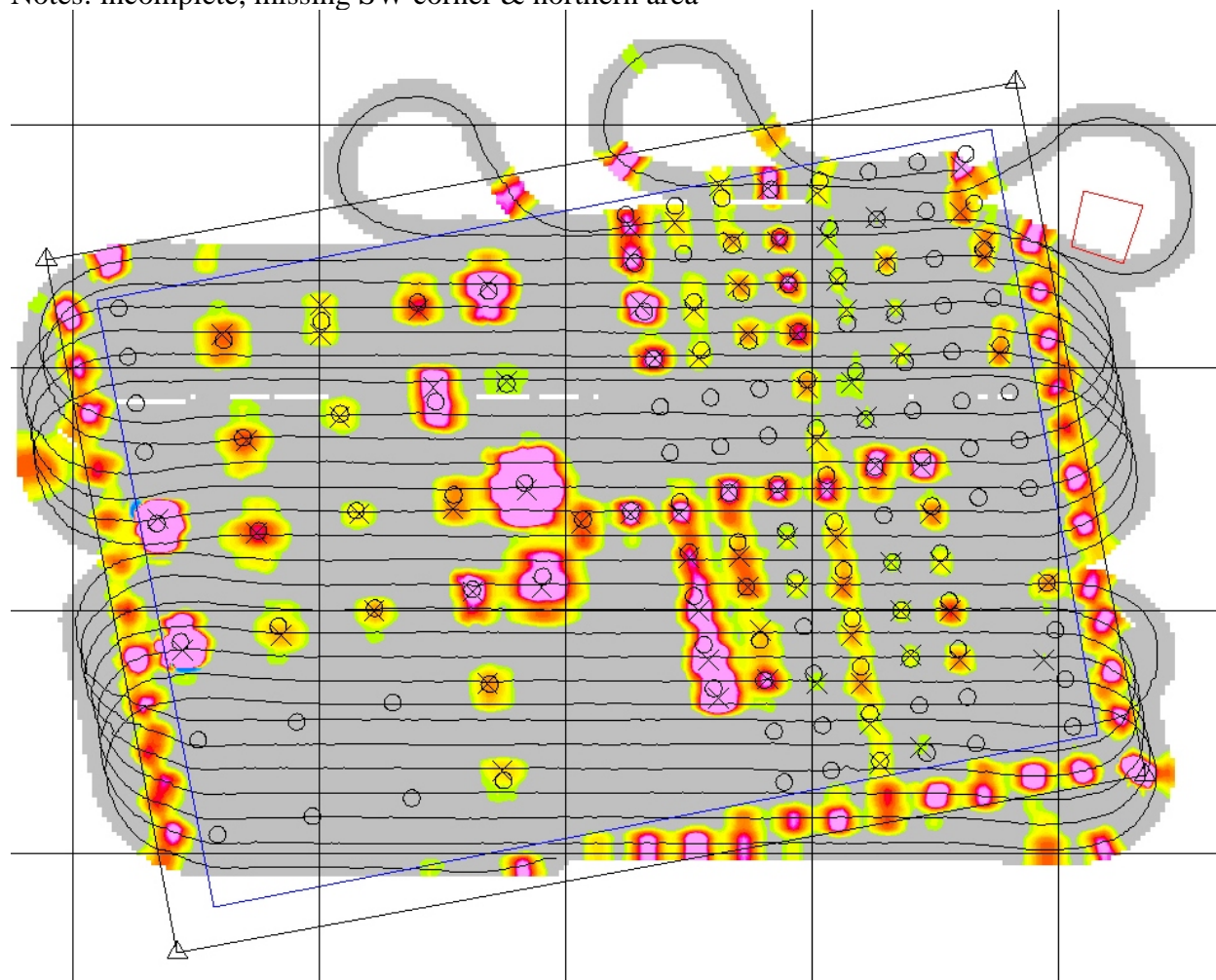
Dig Sheet:
85 of 128 seed items found
3 extra picks
Avg offset dist: 0.33m

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402774.40	4369608.40	660.9	H15	402774.35	4369608.71	0.31
2	402773.40	4369613.80	541.5	F15	402773.39	4369613.59	0.21
3	402788.40	4369615.00	359.9	F11	402788.33	4369615.26	0.27
4	402796.20	4369606.40	66.3	K08	402796.00	4369606.80	0.45
5	402795.80	4369608.00	50.8	J08	402795.60	4369608.60	0.63
6	402784.60	4369619.20	38.6	D12	402784.71	4369618.61	0.60
7	402786.80	4369623.40	37.7	B11	402786.88	4369623.16	0.25
8	402793.00	4369622.60	36.7	C08	402793.19	4369622.32	0.34
9	402789.00	4369611.00	35.0	H11	402789.06	4369611.40	0.40
10	402795.40	4369610.00	33.4	I08	402795.20	4369610.60	0.63
11	402786.20	4369610.80	30.8	H12	402786.20	4369610.89	0.09
12	402804.40	4369616.00	29.7	G03	402804.49	4369616.31	0.32
13	402792.60	4369614.00	25.3	G09	402792.64	4369614.11	0.12
14	402806.02	4369628.30	25.2	A01	402806.23	4369628.81	0.55

15	402798.20	4369627.40	24.2	A05	402798.32	4369627.35	0.13
16	402802.60	4369616.00	24.0	G04	402802.54	4369615.92	0.10
17	402794.60	4369614.00	23.4	G08	402794.62	4369614.48	0.48
18	402792.60	4369624.60	22.7	B08	402792.80	4369624.31	0.35
19	402793.60	4369620.40	22.5	D08	402793.56	4369620.36	0.06
20	402799.00	4369623.60	22.3	C05	402799.05	4369623.43	0.18
21	402796.60	4369615.00	22.2	G07	402796.62	4369614.85	0.15
22	402798.60	4369615.00	21.0	G06	402798.57	4369615.20	0.20
23	402792.60	4369625.80	19.7	A08	402792.43	4369626.30	0.53
24	402800.60	4369615.00	19.0	G05	402800.57	4369615.58	0.58
25	402798.20	4369607.20	18.6	K07	402798.05	4369607.13	0.17
26	402798.60	4369625.20	17.8	B05	402798.67	4369625.38	0.19
27	402795.00	4369612.20	17.3	H08	402795.00	4369612.40	0.20
28	402799.40	4369621.40	15.9	D05	402799.43	4369621.48	0.09
29	402777.40	4369613.20	15.3	F14	402777.51	4369613.29	0.14
30	402784.00	4369622.40	14.4	B12	402783.97	4369622.69	0.29
31	402805.60	4369610.00	13.7	J03	402805.56	4369610.40	0.40
32	402797.40	4369611.00	12.7	I07	402797.32	4369610.97	0.09
33	402777.00	4369617.00	12.4	D14	402776.88	4369617.12	0.17
34	402790.60	4369613.60	12.3	G10	402790.70	4369613.75	0.18
35	402797.03	4369612.23	11.8	H07	402796.98	4369612.83	0.60
36	402776.00	4369621.40	11.3	B14	402776.10	4369621.14	0.28
37	402807.60	4369620.60	11.3	E01	402807.66	4369620.93	0.34
38	402801.20	4369611.00	11.0	I05	402801.27	4369611.67	0.67
39	402807.00	4369624.60	11.0	C01	402806.96	4369624.87	0.27
40	402806.00	4369626.40	10.2	B01	402806.58	4369626.78	0.69
41	402785.40	4369614.20	10.0	F12	402785.44	4369614.77	0.57
42	402804.80	4369614.00	9.7	H03	402804.86	4369614.29	0.30
43	402807.00	4369625.20	9.3				
44	402806.00	4369608.00	9.2	K03	402805.92	4369608.42	0.43
45	402809.60	4369611.20	8.7	J01	402809.53	4369611.13	0.10
46	402797.40	4369621.40	8.6	D06	402797.44	4369621.11	0.29
47	402786.80	4369607.00	8.5	J12	402786.91	4369606.98	0.11
48	402803.00	4369624.40	8.4	C03	402803.04	4369624.15	0.25
49	402797.00	4369623.40	8.3	C06	402797.14	4369623.09	0.34
50	402802.00	4369607.00	8.3	K05	402801.97	4369607.70	0.70
51	402801.60	4369609.00	8.2	J05	402801.62	4369609.66	0.66
52	402799.80	4369619.20	7.8	E05	402799.80	4369619.50	0.30
53	402782.20	4369610.00	7.6	H13	402782.23	4369610.10	0.10
54	402796.80	4369625.20	7.6	B06	402796.75	4369625.06	0.15
55	402801.00	4369613.00	7.4	H05	402800.90	4369613.66	0.67
56	402778.40	4369609.00	7.1	H14	402778.33	4369609.36	0.37
57	402797.90	4369609.20	6.3	J07	402797.87	4369608.79	0.41
58	402794.40	4369626.00	5.6	A07	402794.43	4369626.67	0.67
59	402787.40	4369603.40	5.5	L12	402787.47	4369603.01	0.40
60	402800.20	4369617.00	5.0	F05	402800.16	4369617.52	0.52
61	402795.20	4369622.40	4.8	C07	402795.19	4369622.72	0.32
62	402795.40	4369620.40	4.6	D07	402795.50	4369620.73	0.34
63	402780.00	4369622.60	4.6				
64	402800.20	4369627.20	4.5	A04	402800.30	4369627.71	0.52
65	402780.80	4369618.00	4.5	D13	402780.84	4369618.10	0.11
66	402780.00	4369621.40	4.2	B13	402780.07	4369621.92	0.52
67	402781.60	4369614.00	4.2	F13	402781.48	4369614.12	0.17

68	402805.20	4369612.00	4.2	I03	402805.20	4369612.37	0.37
69	402796.22	4369627.53	3.9	A06	402796.33	4369626.99	0.55
70	402802.74	4369603.71	3.8	M05	402802.76	4369603.81	0.11
71	402799.40	4369611.00	3.7	I06	402799.31	4369611.32	0.33
72	402803.60	4369620.60	3.5	E03	402803.77	4369620.22	0.42
73	402803.60	4369610.00	3.4	J04	402803.61	4369610.01	0.01
74	402802.34	4369605.34	3.2	L05	402802.35	4369605.75	0.41
75	402804.00	4369608.20	3.2	K04	402804.00	4369608.02	0.18
76	402801.00	4369623.60	3.2	C04	402801.06	4369623.77	0.18
77	402799.00	4369613.00	3.0	H06	402798.95	4369613.28	0.28
78	402803.40	4369622.40	2.9	D03	402803.37	4369622.18	0.22
79	402801.40	4369622.40	2.8	D04	402801.41	4369621.82	0.58
80	402800.60	4369625.40	2.7	B04	402800.70	4369625.73	0.34
81	402803.20	4369612.00	2.6	I04	402803.26	4369612.00	0.06
82	402787.56	4369619.44	2.2	D11	402787.59	4369619.34	0.10
83	402800.20	4369607.00	2.1	K06	402800.07	4369607.41	0.43
84	402804.40	4369604.40	2.0	M04	402804.66	4369604.14	0.37
85	402801.60	4369619.40	2.0	E04	402801.77	4369619.85	0.48
86	402802.20	4369618.00	1.9	F04	402802.17	4369617.87	0.13
87	402809.40	4369608.00	1.6				
88	402802.60	4369626.20	1.5	B03	402802.63	4369626.12	0.09

RMP400 Robot-towed EM61MK2, 5/18/07, Grid NS

Notes: complete coverage; ~3s time jump (2.45m jump); GPS path looks jumpier
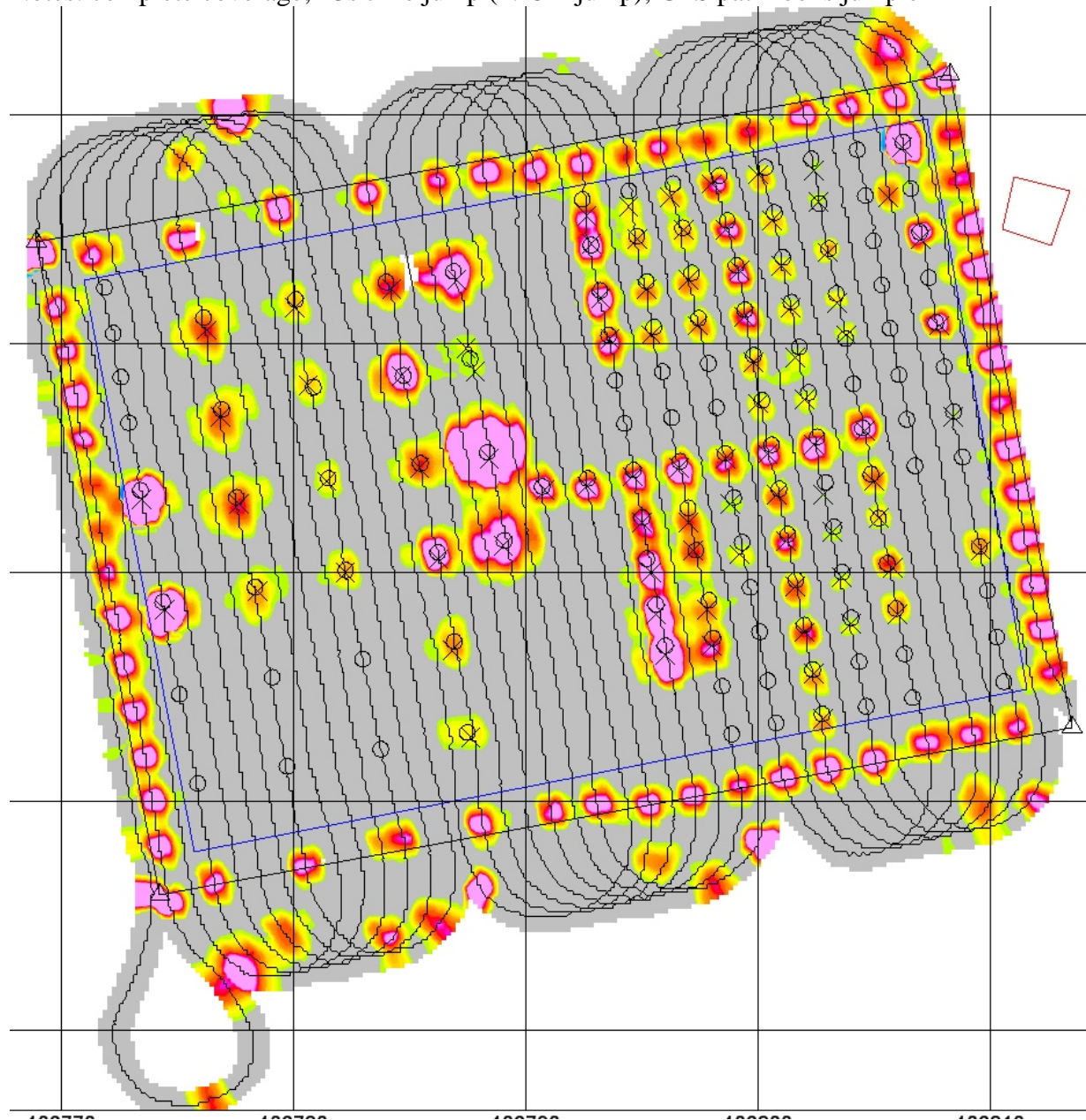
Dig Sheet:

87 of 128 seed items
found
1 extra picks
Avg offset dist: 0.31m

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.40	4369613.20	767.5	F15	402773.39	4369613.59	0.39
2	402774.40	4369608.40	656.0	H15	402774.35	4369608.71	0.31
3	402788.40	4369615.00	374.8	F11	402788.33	4369615.26	0.27
4	402806.20	4369628.60	289.4	A01	402806.23	4369628.81	0.21
5	402796.00	4369606.40	91.1	K08	402796.00	4369606.80	0.40

6	402795.60	4369608.20	47.3	J08	402795.60	4369608.60	0.40
7	402784.60	4369618.60	43.2	D12	402784.71	4369618.61	0.11
8	402786.20	4369610.60	42.1	H12	402786.20	4369610.89	0.29
9	402793.20	4369622.00	40.5	C08	402793.19	4369622.32	0.32
10	402796.60	4369614.60	38.8	G07	402796.62	4369614.85	0.25
11	402789.00	4369611.20	35.7	H11	402789.06	4369611.40	0.21
12	402807.00	4369624.60	34.2	C01	402806.96	4369624.87	0.27
13	402795.40	4369610.00	32.6	I08	402795.20	4369610.60	0.63
14	402787.00	4369622.80	32.3	B11	402786.88	4369623.16	0.38
15	402804.60	4369616.20	30.2	G03	402804.49	4369616.31	0.16
16	402790.80	4369613.60	30.1	G10	402790.70	4369613.75	0.18
17	402792.80	4369624.40	29.6	B08	402792.80	4369624.31	0.09
18	402807.80	4369620.80	29.6	E01	402807.66	4369620.93	0.19
19	402802.40	4369615.60	29.2	G04	402802.54	4369615.92	0.35
20	402792.60	4369613.80	27.2	G09	402792.64	4369614.11	0.31
21	402799.20	4369623.20	25.7	C05	402799.05	4369623.43	0.27
22	402794.60	4369614.20	25.6	G08	402794.62	4369614.48	0.28
23	402793.60	4369620.20	24.3	D08	402793.56	4369620.36	0.16
24	402800.40	4369615.20	24.2	G05	402800.57	4369615.58	0.42
25	402792.60	4369625.60	24.0	A08	402792.43	4369626.30	0.72
26	402798.00	4369627.00	21.7	A05	402798.32	4369627.35	0.47
27	402799.40	4369621.20	21.3	D05	402799.43	4369621.48	0.28
28	402798.60	4369625.00	20.3	B05	402798.67	4369625.38	0.39
29	402798.00	4369606.80	19.4	K07	402798.05	4369607.13	0.33
30	402801.20	4369611.40	19.1	I05	402801.27	4369611.67	0.28
31	402798.60	4369615.00	19.0	G06	402798.57	4369615.20	0.20
32	402795.00	4369612.20	16.8	H08	402795.00	4369612.40	0.20
33	402802.00	4369607.40	15.9	K05	402801.97	4369607.70	0.30
34	402784.20	4369622.40	15.5	B12	402783.97	4369622.69	0.37
35	402777.60	4369613.00	14.8	F14	402777.51	4369613.29	0.30
36	402805.80	4369610.20	14.8	J03	402805.56	4369610.40	0.31
37	402785.40	4369614.60	14.1	F12	402785.44	4369614.77	0.17
38	402776.20	4369620.60	14.0	B14	402776.10	4369621.14	0.55
39	402797.20	4369611.00	13.6	I07	402797.32	4369610.97	0.12
40	402800.80	4369613.40	13.0	H05	402800.90	4369613.66	0.28
41	402797.00	4369612.20	13.0	H07	402796.98	4369612.83	0.63
42	402801.60	4369609.40	13.0	J05	402801.62	4369609.66	0.26
43	402805.00	4369614.00	12.1	H03	402804.86	4369614.29	0.32
44	402776.80	4369616.80	11.9	D14	402776.88	4369617.12	0.33
45	402805.60	4369626.40	11.5	B02	402804.62	4369626.47	0.98
46	402795.20	4369622.40	10.9	C07	402795.19	4369622.72	0.32
47	402797.80	4369608.40	10.6	J07	402797.87	4369608.79	0.40
48	402799.80	4369619.20	10.2	E05	402799.80	4369619.50	0.30
49	402797.00	4369622.80	10.2	C06	402797.14	4369623.09	0.32
50	402797.40	4369620.80	10.1	D06	402797.44	4369621.11	0.31
51	402806.00	4369608.20	9.5	K03	402805.92	4369608.42	0.23
52	402809.60	4369611.00	9.1	J01	402809.53	4369611.13	0.15
53	402795.40	4369620.40	9.0	D07	402795.50	4369620.73	0.34
54	402803.00	4369624.00	9.0	C03	402803.04	4369624.15	0.16
55	402802.80	4369603.60	8.9	M05	402802.76	4369603.81	0.21
56	402786.80	4369606.60	8.6	J12	402786.91	4369606.98	0.40
57	402802.40	4369605.60	8.6	L05	402802.35	4369605.75	0.16
58	402800.00	4369627.40	8.0	A04	402800.30	4369627.71	0.43

59	402794.80	4369624.60	7.9	B07	402794.78	4369624.69	0.09
60	402796.80	4369625.00	7.8	B06	402796.75	4369625.06	0.08
61	402778.40	4369609.20	7.6	H14	402778.33	4369609.36	0.17
62	402782.20	4369610.00	7.5	H13	402782.23	4369610.10	0.10
63	402796.20	4369626.40	7.2	A06	402796.33	4369626.99	0.60
64	402801.00	4369623.40	6.5	C04	402801.06	4369623.77	0.37
65	402780.00	4369621.60	6.4	B13	402780.07	4369621.92	0.33
66	402800.60	4369625.40	6.4	B04	402800.70	4369625.73	0.34
67	402780.60	4369618.20	6.2	D13	402780.84	4369618.10	0.26
68	402801.40	4369621.60	6.0	D04	402801.41	4369621.82	0.22
69	402805.20	4369612.40	5.8	I03	402805.20	4369612.37	0.03
70	402800.00	4369617.40	5.4	F05	402800.16	4369617.52	0.20
71	402794.40	4369626.00	4.8	A07	402794.43	4369626.67	0.67
72	402781.40	4369614.00	4.8	F13	402781.48	4369614.12	0.14
73	402787.60	4369602.80	4.4	L12	402787.47	4369603.01	0.25
74	402802.00	4369617.60	4.3	F04	402802.17	4369617.87	0.32
75	402804.00	4369607.80	4.0	K04	402804.00	4369608.02	0.22
76	402803.40	4369621.80	3.9	D03	402803.37	4369622.18	0.38
77	402803.60	4369609.80	3.9	J04	402803.61	4369610.01	0.21
78	402803.80	4369620.40	3.6	E03	402803.77	4369620.22	0.18
79	402799.20	4369610.80	3.5	I06	402799.31	4369611.32	0.53
80	402801.60	4369619.40	3.3	E04	402801.77	4369619.85	0.48
81	402802.60	4369626.20	3.0	B03	402802.63	4369626.12	0.09
82	402803.20	4369611.80	2.7	I04	402803.26	4369612.00	0.21
83	402787.40	4369619.80	2.6	D11	402787.59	4369619.34	0.50
84	402787.80	4369618.80	2.5				
85	402798.80	4369613.00	2.5	H06	402798.95	4369613.28	0.32
86	402802.40	4369627.60	2.2	A03	402802.29	4369628.07	0.48
87	402808.40	4369616.80	1.9	G01	402808.42	4369617.03	0.23
88	402802.80	4369613.40	1.6	H04	402802.90	4369613.93	0.54

RMP400 Robot-towed EM61MK2, 5/18/07, Grid NS, Offset from items
Notes: complete coverage; ~3s time jump (2.45m jump); GPS path looks jumpier
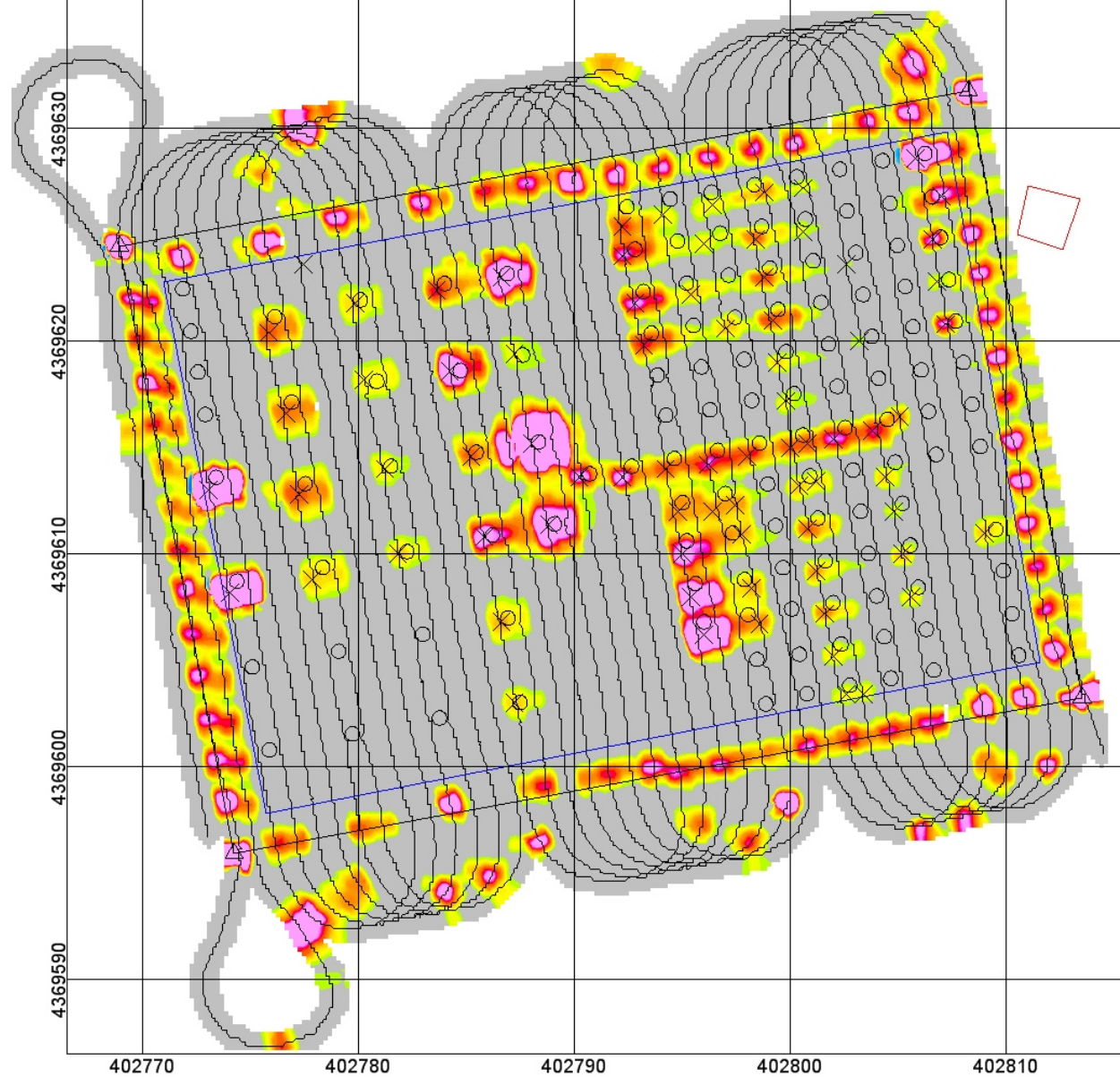
Dig Sheet:

71 of 128 seed items found
6 extra picks
Avg offset dist: 0.56m

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.00	4369613.00	424.9	F15	402773.39	4369613.59	0.71
2	402788.00	4369615.20	381.8	F11	402788.33	4369615.26	0.34
3	402774.00	4369608.20	290.7	H15	402774.35	4369608.71	0.62
4	402805.80	4369628.60	181.2	A01	402806.23	4369628.81	0.48
5	402796.00	4369606.20	56.5	K08	402796.00	4369606.80	0.60
6	402795.40	4369608.00	40.4	J08	402795.60	4369608.60	0.63
7	402786.60	4369623.00	37.8	B11	402786.88	4369623.16	0.32

8	402784.20	4369618.60	34.4	D12	402784.71	4369618.61	0.51
9	402788.80	4369611.40	34.4	H11	402789.06	4369611.40	0.26
10	402785.80	4369610.80	30.5	H12	402786.20	4369610.89	0.41
11	402795.00	4369610.00	23.3	I08	402795.20	4369610.60	0.63
12	402806.60	4369624.80	21.1	C01	402806.96	4369624.87	0.37
13	402807.00	4369626.80	20.7	B01	402806.58	4369626.78	0.42
14	402792.20	4369613.60	20.5	G09	402792.64	4369614.11	0.67
15	402790.20	4369613.60	20.2	G10	402790.70	4369613.75	0.52
16	402807.20	4369620.80	19.5	E01	402807.66	4369620.93	0.48
17	402792.80	4369621.80	18.7	C08	402793.19	4369622.32	0.65
18	402792.20	4369624.00	17.8	B08	402792.80	4369624.31	0.68
19	402802.00	4369615.40	17.8	G04	402802.54	4369615.92	0.75
20	402796.20	4369614.20	17.7	G07	402796.62	4369614.85	0.77
21	402803.80	4369615.80	15.5				
22	402783.60	4369622.40	14.5	B12	402783.97	4369622.69	0.47
23	402793.20	4369619.80	14.4	D08	402793.56	4369620.36	0.67
24	402792.20	4369625.40	13.5	A08	402792.43	4369626.30	0.93
25	402794.20	4369614.00	13.4	G08	402794.62	4369614.48	0.64
26	402798.00	4369614.60	12.8	G06	402798.57	4369615.20	0.83
27	402798.80	4369623.00	12.6	C05	402799.05	4369623.43	0.50
28	402800.80	4369615.20	12.2	G05	402800.57	4369615.58	0.44
29	402799.20	4369621.00	12.0	D05	402799.43	4369621.48	0.53
30	402800.00	4369615.00	12.0				
31	402777.20	4369612.80	11.9	F14	402777.51	4369613.29	0.58
32	402775.80	4369620.40	11.8	B14	402776.10	4369621.14	0.80
33	402785.20	4369614.60	11.5	F12	402785.44	4369614.77	0.29
34	402800.80	4369611.20	10.7	I05	402801.27	4369611.67	0.66
35	402798.40	4369624.80	10.6	B05	402798.67	4369625.38	0.64
36	402776.60	4369616.60	10.2	D14	402776.88	4369617.12	0.59
37	402801.60	4369607.20	9.2	K05	402801.97	4369607.70	0.62
38	402798.60	4369606.70	8.7	K07	402798.05	4369607.13	0.70
39	402798.80	4369627.00	8.4	A05	402798.32	4369627.35	0.59
40	402794.80	4369612.00	8.2	H08	402795.00	4369612.40	0.45
41	402801.20	4369609.20	8.1	J05	402801.62	4369609.66	0.62
42	402805.10	4369616.50	8.1	G03	402804.49	4369616.31	0.64
43	402796.40	4369612.00	7.9				
44	402786.60	4369606.80	7.4	J12	402786.91	4369606.98	0.36
45	402797.40	4369612.30	7.4	H07	402796.98	4369612.83	0.68
46	402797.70	4369610.90	7.1	I07	402797.32	4369610.97	0.39
47	402798.20	4369608.40	7.0	J07	402797.87	4369608.79	0.51
48	402797.00	4369620.60	6.3	D06	402797.44	4369621.11	0.67
49	402805.20	4369610.00	6.3	J03	402805.56	4369610.40	0.54
50	402800.40	4369613.20	6.2				
51	402809.00	4369611.00	6.2	J01	402809.53	4369611.13	0.55
52	402795.40	4369622.20	6.0	C07	402795.19	4369622.72	0.56
53	402777.80	4369608.80	5.9	H14	402778.33	4369609.36	0.77
54	402779.80	4369621.80	5.9	B13	402780.07	4369621.92	0.30
55	402781.80	4369610.00	5.9	H13	402782.23	4369610.10	0.44
56	402804.40	4369613.60	5.7	H03	402804.86	4369614.29	0.83
57	402787.20	4369603.00	5.5	L12	402787.47	4369603.01	0.27
58	402799.40	4369619.00	5.5	E05	402799.80	4369619.50	0.64
59	402801.20	4369613.40	4.9	H05	402800.90	4369613.66	0.40
60	402781.20	4369614.00	4.8	F13	402781.48	4369614.12	0.30

61	402802.00	4369605.20	4.7	L05	402802.35	4369605.75	0.65
62	402805.60	4369608.00	4.5	K03	402805.92	4369608.42	0.53
63	402780.20	4369618.20	4.2	D13	402780.84	4369618.10	0.65
64	402796.00	4369624.60	3.9	B06	402796.75	4369625.06	0.88
65	402799.80	4369617.20	3.7	F05	402800.16	4369617.52	0.48
66	402803.40	4369603.40	3.7				
67	402796.40	4369626.40	3.6	A06	402796.33	4369626.99	0.59
68	402802.60	4369603.40	3.6	M05	402802.76	4369603.81	0.44
69	402794.10	4369626.00	3.5	A07	402794.43	4369626.67	0.75
70	402806.80	4369622.80	3.1	D01	402807.35	4369622.88	0.56
71	402800.60	4369627.20	3.0	A04	402800.30	4369627.71	0.59
72	402787.20	4369619.40	2.8	D11	402787.59	4369619.34	0.39
73	402804.80	4369612.00	2.8	I03	402805.20	4369612.37	0.54
74	402800.60	4369625.10	2.8	B04	402800.70	4369625.73	0.64
75	402803.20	4369620.00	2.3	E03	402803.77	4369620.22	0.61
76	402802.60	4369623.60	2.0	C03	402803.04	4369624.15	0.70
77	402777.40	4369623.60	1.7				

RMP400 Robot-towed EM61MK2, 5/19/07, Grid EW
Notes: Missing Northern area, small gap due to soil sensor avoidance
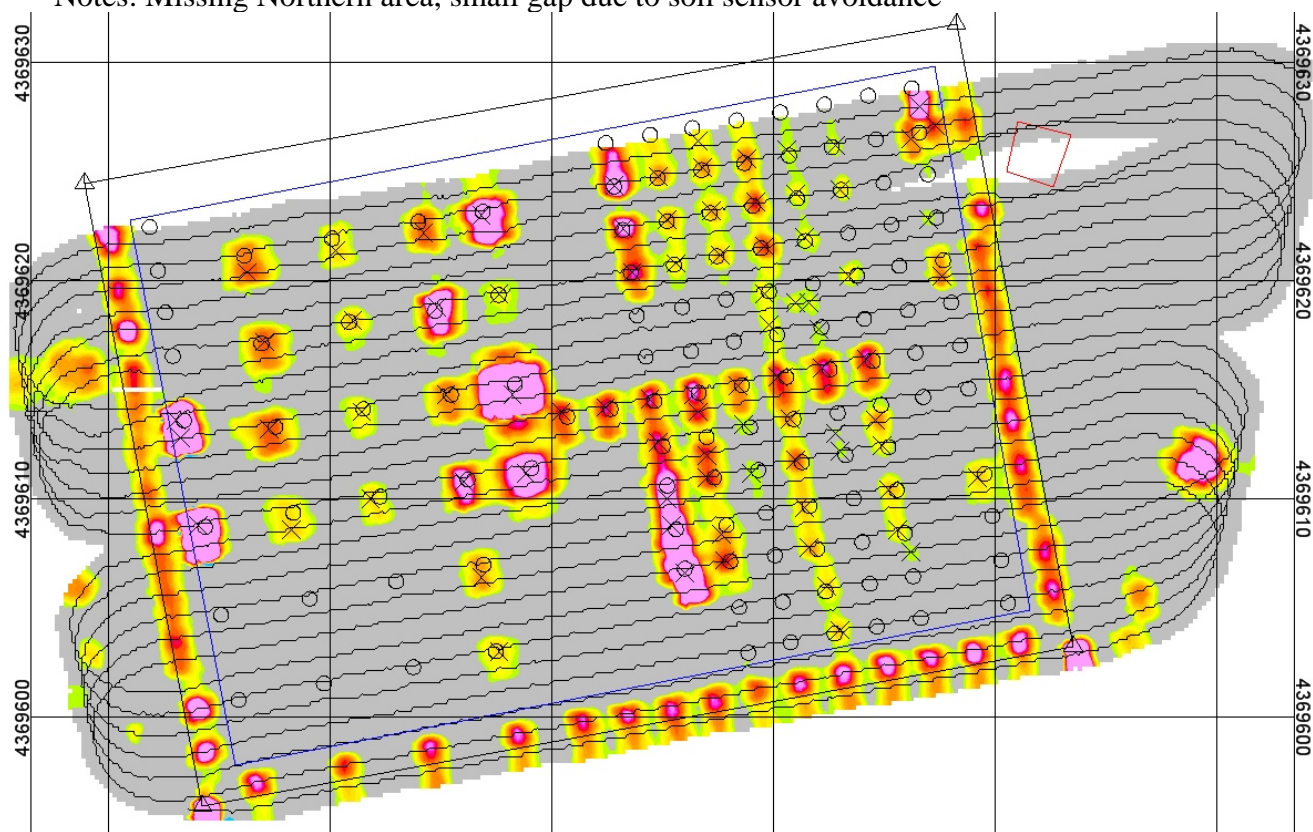
Dig Sheet:

78 of 128 seed items found
5 extra picks
Avg offset dist: **0.34**m

note: missing northern-most line over seed items

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402774.00	4369608.80	338.5	H15	402774.35	4369608.71	0.36
2	402788.20	4369614.80	311.5	F11	402788.33	4369615.26	0.48
3	402773.20	4369612.80	193.8				
4	402773.00	4369613.60	157.8	F15	402773.39	4369613.59	0.39
5	402796.00	4369606.60	81.5	K08	402796.00	4369606.80	0.20
6	402784.80	4369618.80	56.4	D12	402784.71	4369618.61	0.21
7	402806.60	4369628.00	38.4	A01	402806.23	4369628.81	0.89
8	402786.80	4369623.00	38.2	B11	402786.88	4369623.16	0.18
9	402788.80	4369611.20	36.5	H11	402789.06	4369611.40	0.33
10	402795.40	4369608.80	35.7	J08	402795.60	4369608.60	0.28
11	402792.80	4369624.40	32.9	B08	402792.80	4369624.31	0.09
12	402795.20	4369610.00	30.2	I08	402795.20	4369610.60	0.60
13	402786.00	4369610.80	23.3	H12	402786.20	4369610.89	0.22
14	402793.20	4369622.40	23.2	C08	402793.19	4369622.32	0.08
15	402796.40	4369614.80	18.6	G07	402796.62	4369614.85	0.23
16	402793.60	4369620.40	16.5	D08	402793.56	4369620.36	0.06
17	402794.40	4369614.60	16.3	G08	402794.62	4369614.48	0.25
18	402802.20	4369616.00	16.1	G04	402802.54	4369615.92	0.35
19	402792.40	4369614.20	15.8	G09	402792.64	4369614.11	0.26

20	402804.20	4369616.40	15.8	G03	402804.49	4369616.31	0.30
21	402794.80	4369612.60	15.5	H08	402795.00	4369612.40	0.28
22	402797.80	4369607.20	14.7	K07	402798.05	4369607.13	0.26
23	402796.60	4369614.00	14.5				
24	402800.20	4369615.60	14.4	G05	402800.57	4369615.58	0.37
25	402790.40	4369614.00	14.3	G10	402790.70	4369613.75	0.39
26	402799.20	4369623.60	14.3	C05	402799.05	4369623.43	0.23
27	402799.60	4369621.60	13.8	D05	402799.43	4369621.48	0.21
28	402797.00	4369611.00	13.6	I07	402797.32	4369610.97	0.32
29	402797.00	4369612.00	13.6	H07	402796.98	4369612.83	0.83
30	402807.30	4369627.10	12.9				
31	402776.20	4369620.40	12.4	B14	402776.10	4369621.14	0.75
32	402801.00	4369611.80	12.0	I05	402801.27	4369611.67	0.30
33	402777.20	4369613.20	11.6	F14	402777.51	4369613.29	0.32
34	402777.00	4369617.20	11.3	D14	402776.88	4369617.12	0.14
35	402784.20	4369622.20	11.3	B12	402783.97	4369622.69	0.54
36	402798.40	4369615.20	10.2	G06	402798.57	4369615.20	0.17
37	402798.80	4369625.60	10.2	B05	402798.67	4369625.38	0.26
38	402807.60	4369620.20	10.2	E01	402807.66	4369620.93	0.73
39	402806.20	4369626.50	9.6	B01	402806.58	4369626.78	0.47
40	402785.20	4369614.80	9.4	F12	402785.44	4369614.77	0.24
41	402804.60	4369613.60	9.2	H03	402804.86	4369614.29	0.74
42	402797.60	4369608.40	8.6	J07	402797.87	4369608.79	0.47
43	402796.80	4369625.20	8.5	B06	402796.75	4369625.06	0.15
44	402794.80	4369624.80	8.4	B07	402794.78	4369624.69	0.11
45	402786.80	4369606.40	8.2	J12	402786.91	4369606.98	0.59
46	402800.70	4369613.70	7.7	H05	402800.90	4369613.66	0.20
47	402797.20	4369623.20	7.6	C06	402797.14	4369623.09	0.13
48	402795.20	4369622.80	7.4	C07	402795.19	4369622.72	0.08
49	402801.60	4369607.80	7.3	K05	402801.97	4369607.70	0.38
50	402797.60	4369621.20	6.7	D06	402797.44	4369621.11	0.18
51	402805.20	4369610.40	6.5	J03	402805.56	4369610.40	0.36
52	402801.40	4369609.60	6.3	J05	402801.62	4369609.66	0.23
53	402803.00	4369604.00	6.2	M05	402802.76	4369603.81	0.31
54	402781.00	4369618.20	6.0	D13	402780.84	4369618.10	0.19
55	402778.20	4369608.60	5.8	H14	402778.33	4369609.36	0.77
56	402802.40	4369606.00	5.8	L05	402802.35	4369605.75	0.25
57	402809.20	4369611.00	5.7	J01	402809.53	4369611.13	0.35
58	402787.60	4369603.00	5.5	L12	402787.47	4369603.01	0.13
59	402781.80	4369610.00	5.2	H13	402782.23	4369610.10	0.44
60	402780.20	4369621.40	5.1	B13	402780.07	4369621.92	0.54
61	402803.00	4369624.20	5.0	C03	402803.04	4369624.15	0.06
62	402803.40	4369620.20	5.0	E03	402803.77	4369620.22	0.37
63	402795.60	4369620.80	4.9	D07	402795.50	4369620.73	0.12
64	402805.60	4369608.60	4.9	K03	402805.92	4369608.42	0.37
65	402804.90	4369612.40	4.5	I03	402805.20	4369612.37	0.30
66	402796.60	4369626.40	4.4	A06	402796.33	4369626.99	0.65
67	402781.40	4369614.00	4.2	F13	402781.48	4369614.12	0.14
68	402801.00	4369624.00	4.1	C04	402801.06	4369623.77	0.24
69	402799.60	4369619.40	3.8	E05	402799.80	4369619.50	0.22
70	402799.80	4369618.00	3.7	F05	402800.16	4369617.52	0.60
71	402801.40	4369622.00	3.6	D04	402801.41	4369621.82	0.18
72	402802.80	4369626.20	3.2	B03	402802.63	4369626.12	0.19

73	402801.00	4369619.00	3.1				
74	402787.60	4369619.40	3.0	D11	402787.59	4369619.34	0.06
75	402800.60	4369626.00	2.8	B04	402800.70	4369625.73	0.29
76	402801.60	4369619.00	2.8	E04	402801.77	4369619.85	0.87
77	402807.00	4369622.80	2.6	D01	402807.35	4369622.88	0.36
78	402806.20	4369607.60	2.2				
79	402798.60	4369613.40	2.1	H06	402798.95	4369613.28	0.37
80	402799.00	4369611.20	2.0	I06	402799.31	4369611.32	0.33
81	402803.00	4369612.20	2.0	I04	402803.26	4369612.00	0.33
82	402802.00	4369617.80	1.8	F04	402802.17	4369617.87	0.18
83	402802.80	4369613.00	1.6	H04	402802.90	4369613.93	0.94

RMP400 Robot-towed EM61MK2, 5/19/07, True EW (merged part 1 & 2)
Notes: 3 overlapping/repeat lines; 2 small gaps: one ~1.2m where data collection stopped in line
& one due to soil sensor avoidance
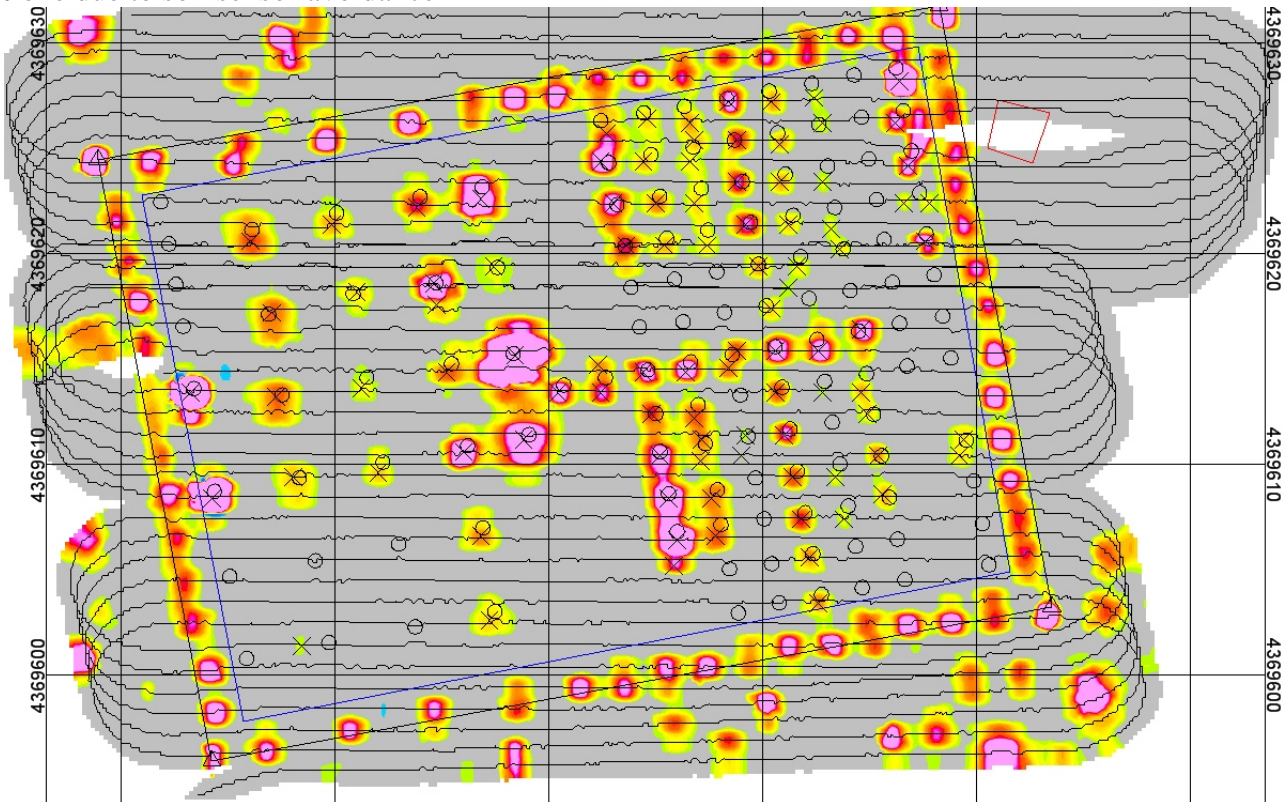
Dig Sheet:

84 of 128 seed items found
11 extra picks
Avg offset dist: 0.41m

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.20	4369613.40	768.6	F15	402773.39	4369613.59	0.27
2	402774.20	4369608.40	729.0	H15	402774.35	4369608.71	0.34
3	402788.40	4369615.20	395.1	F11	402788.33	4369615.26	0.09
4	402806.40	4369628.20	252.1	A01	402806.23	4369628.81	0.63
5	402796.00	4369606.40	82.2	K08	402796.00	4369606.80	0.40
6	402795.60	4369608.40	43.6	J08	402795.60	4369608.60	0.20
7	402784.60	4369618.60	40.9	D12	402784.71	4369618.61	0.11
8	402786.00	4369610.60	40.9	H12	402786.20	4369610.89	0.35
9	402786.80	4369622.60	40.0	B11	402786.88	4369623.16	0.57
10	402788.80	4369611.20	37.3	H11	402789.06	4369611.40	0.33
11	402792.40	4369624.40	33.2	B08	402792.80	4369624.31	0.41
12	402796.40	4369614.40	33.2	G07	402796.62	4369614.85	0.50
13	402802.60	4369615.40	28.6	G04	402802.54	4369615.92	0.52
14	402795.20	4369610.40	28.0	I08	402795.20	4369610.60	0.20
15	402800.60	4369615.40	27.4	G05	402800.57	4369615.58	0.18
16	402790.40	4369613.40	25.9	G10	402790.70	4369613.75	0.46
17	402806.80	4369624.20	25.6	C01	402806.96	4369624.87	0.69
18	402807.60	4369620.60	25.6	E01	402807.66	4369620.93	0.34
19	402804.60	4369616.40	25.3	G03	402804.49	4369616.31	0.14

20	402798.40	4369627.20	25.2	A05	402798.32	4369627.35	0.17
21	402793.00	4369622.40	23.6	C08	402793.19	4369622.32	0.21
22	402794.40	4369614.40	22.2	G08	402794.62	4369614.48	0.23
23	402806.20	4369626.20	21.6	B01	402806.58	4369626.78	0.69
24	402801.00	4369611.40	19.0	I05	402801.27	4369611.67	0.38
25	402792.40	4369613.40	18.2				
26	402795.80	4369605.20	18.0				
27	402799.20	4369621.40	17.7	D05	402799.43	4369621.48	0.24
28	402798.80	4369623.40	17.6	C05	402799.05	4369623.43	0.25
29	402783.80	4369622.20	16.4	B12	402783.97	4369622.69	0.52
30	402793.60	4369620.40	15.6	D08	402793.56	4369620.36	0.06
31	402798.80	4369625.40	15.3	B05	402798.67	4369625.38	0.13
32	402794.80	4369612.40	14.8	H08	402795.00	4369612.40	0.20
33	402801.80	4369607.40	14.7	K05	402801.97	4369607.70	0.34
34	402776.00	4369620.60	13.5	B14	402776.10	4369621.14	0.55
35	402797.80	4369606.60	12.8	K07	402798.05	4369607.13	0.59
36	402801.40	4369609.40	12.6	J05	402801.62	4369609.66	0.34
37	402796.80	4369612.20	12.5	H07	402796.98	4369612.83	0.66
38	402798.80	4369615.40	12.4	G06	402798.57	4369615.20	0.30
39	402800.60	4369613.40	12.4	H05	402800.90	4369613.66	0.40
40	402792.70	4369625.70	12.1	A08	402792.43	4369626.30	0.66
41	402785.20	4369614.40	11.6	F12	402785.44	4369614.77	0.44
42	402777.20	4369613.20	11.1	F14	402777.51	4369613.29	0.32
43	402777.00	4369617.20	10.7	D14	402776.88	4369617.12	0.14
44	402798.40	4369614.60	10.5				
45	402797.60	4369608.40	10.2	J07	402797.87	4369608.79	0.47
46	402797.10	4369611.20	10.0	I07	402797.32	4369610.97	0.32
47	402795.00	4369622.40	9.9	C07	402795.19	4369622.72	0.37
48	402786.80	4369606.60	9.4	J12	402786.91	4369606.98	0.40
49	402802.60	4369603.40	9.1	M05	402802.76	4369603.81	0.44
50	402805.40	4369610.40	8.7	J03	402805.56	4369610.40	0.16
51	402802.20	4369605.60	8.6	L05	402802.35	4369605.75	0.21
52	402800.40	4369627.20	8.1	A04	402800.30	4369627.71	0.52
53	402792.30	4369614.80	7.9	G09	402792.64	4369614.11	0.77
54	402796.60	4369626.20	7.5	A06	402796.33	4369626.99	0.83
55	402779.80	4369621.40	7.4	B13	402780.07	4369621.92	0.59
56	402800.80	4369625.20	7.4	B04	402800.70	4369625.73	0.54
57	402799.80	4369619.40	7.3	E05	402799.80	4369619.50	0.10
58	402800.80	4369623.40	7.3	C04	402801.06	4369623.77	0.45
59	402804.60	4369613.40	7.1	H03	402804.86	4369614.29	0.93
60	402805.60	4369608.60	6.9	K03	402805.92	4369608.42	0.37
61	402794.40	4369624.40	6.8	B07	402794.78	4369624.69	0.48
62	402795.40	4369620.40	6.4	D07	402795.50	4369620.73	0.34
63	402782.00	4369609.60	6.3	H13	402782.23	4369610.10	0.55
64	402797.10	4369610.20	6.3				
65	402796.80	4369625.40	6.2	B06	402796.75	4369625.06	0.34
66	402778.00	4369609.40	6.1	H14	402778.33	4369609.36	0.33
67	402800.40	4369617.40	5.6	F05	402800.16	4369617.52	0.27
68	402787.20	4369602.60	5.5	L12	402787.47	4369603.01	0.49
69	402794.60	4369626.40	5.4	A07	402794.43	4369626.67	0.32
70	402796.80	4369622.40	5.3	C06	402797.14	4369623.09	0.77
71	402801.20	4369621.40	5.2	D04	402801.41	4369621.82	0.47
72	402781.00	4369618.20	5.1	D13	402780.84	4369618.10	0.19

73	402809.20	4369610.40	4.8				
74	402809.40	4369611.20	4.8	J01	402809.53	4369611.13	0.15
75	402797.40	4369620.40	4.6	D06	402797.44	4369621.11	0.71
76	402804.90	4369612.40	4.6	I03	402805.20	4369612.37	0.30
77	402784.70	4369617.60	4.5				
78	402796.60	4369624.40	4.2				
79	402803.60	4369620.20	4.0	E03	402803.77	4369620.22	0.17
80	402806.60	4369622.40	3.6				
81	402781.20	4369613.60	3.5	F13	402781.48	4369614.12	0.59
82	402801.60	4369619.40	3.5	E04	402801.77	4369619.85	0.48
83	402803.40	4369609.40	3.1	J04	402803.61	4369610.01	0.65
84	402807.80	4369622.40	3.1	D01	402807.35	4369622.88	0.66
85	402803.80	4369607.40	3.0	K04	402804.00	4369608.02	0.65
86	402802.40	4369627.40	2.9	A03	402802.29	4369628.07	0.68
87	402802.80	4369623.40	2.9	C03	402803.04	4369624.15	0.79
88	402803.20	4369621.20	2.9	D03	402803.37	4369622.18	0.99
89	402802.80	4369626.20	2.8	B03	402802.63	4369626.12	0.19
90	402787.40	4369619.40	2.7	D11	402787.59	4369619.34	0.20
91	402778.40	4369601.40	2.4				
92	402801.20	4369618.40	2.4				
93	402802.80	4369613.40	1.9	H04	402802.90	4369613.93	0.54
94	402799.20	4369611.40	1.7	I06	402799.31	4369611.32	0.14
95	402799.00	4369610.40	1.6				

RMP400 Robot-towed EM61MK2, 5/19/07, True NS
Notes: mostly complete; missing eastern end
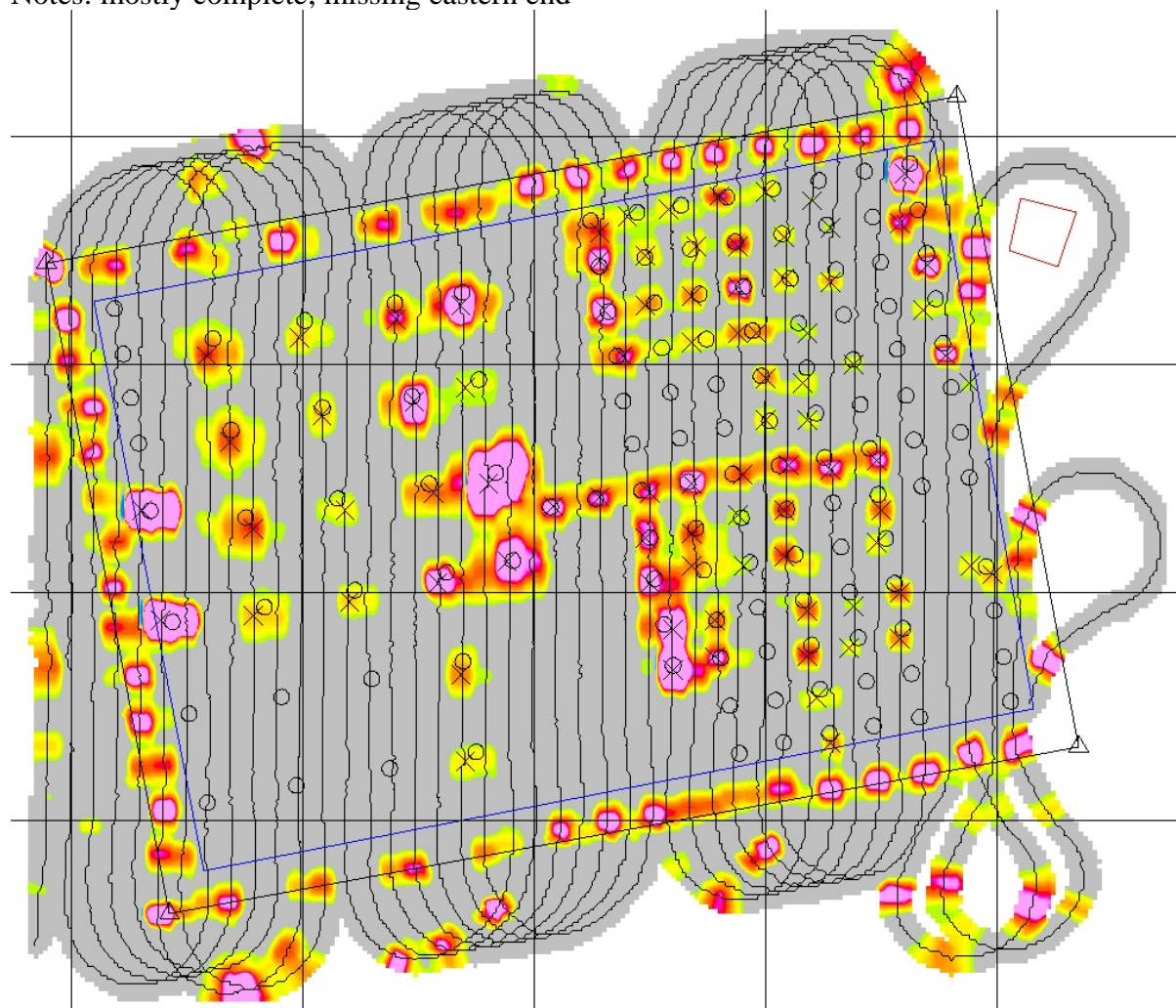
Dig Sheet:

84 of 128 seed items found
2 extra picks
Avg offset dist: 0.44m

Target_ID	X	Y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.00	4369613.60	409.1	F15	402773.39	4369613.59	0.39
2	402788.00	4369614.80	386.7	F11	402788.33	4369615.26	0.57
3	402773.80	4369608.80	333.6	H15	402774.35	4369608.71	0.56
4	402806.00	4369628.40	253.3	A01	402806.23	4369628.81	0.47
5	402796.00	4369606.60	88.2	K08	402796.00	4369606.80	0.20
6	402796.00	4369608.40	46.8	J08	402795.60	4369608.60	0.45
7	402784.80	4369618.40	44.3	D12	402784.71	4369618.61	0.23
8	402786.80	4369622.60	44	B11	402786.88	4369623.16	0.57
9	402788.80	4369611.40	37.2	H11	402789.06	4369611.40	0.26
10	402785.80	4369610.40	33.1	H12	402786.20	4369610.89	0.63
11	402793.00	4369622.40	31.9	C08	402793.19	4369622.32	0.21
12	402807.00	4369624.40	31.7	C01	402806.96	4369624.87	0.47
13	402796.80	4369614.80	29.5	G07	402796.62	4369614.85	0.19

14	402807.80	4369620.40	26.2	E01	402807.66	4369620.93	0.55
15	402792.80	4369624.60	25.4	B08	402792.80	4369624.31	0.29
16	402795.00	4369610.40	24.2	I08	402795.20	4369610.60	0.28
17	402790.80	4369613.80	23.3	G10	402790.70	4369613.75	0.11
18	402798.80	4369623.40	22.5	C05	402799.05	4369623.43	0.25
19	402802.80	4369615.40	21.9	G04	402802.54	4369615.92	0.58
20	402795.00	4369614.40	20.1	G08	402794.62	4369614.48	0.39
21	402804.80	4369615.80	19.8	G03	402804.49	4369616.31	0.60
22	402797.80	4369607.20	19.5	K07	402798.05	4369607.13	0.26
23	402801.00	4369615.60	18.1	G05	402800.57	4369615.58	0.43
24	402792.80	4369614.20	18	G09	402792.64	4369614.11	0.18
25	402794.80	4369612.40	17.8	H08	402795.00	4369612.40	0.20
26	402805.80	4369626.20	17.5	B01	402806.58	4369626.78	0.97
27	402784.00	4369622.00	17.2	B12	402783.97	4369622.69	0.69
28	402793.80	4369620.40	17.1	D08	402793.56	4369620.36	0.24
29	402798.80	4369625.20	16	B05	402798.67	4369625.38	0.22
30	402798.00	4369627.40	15.9	A05	402798.32	4369627.35	0.32
31	402801.80	4369607.20	14.7	K05	402801.97	4369607.70	0.53
32	402800.80	4369613.60	14.1	H05	402800.90	4369613.66	0.12
33	402792.80	4369625.80	13.8	A08	402792.43	4369626.30	0.62
34	402800.80	4369611.60	13.8	I05	402801.27	4369611.67	0.48
35	402775.80	4369620.40	13.7	B14	402776.10	4369621.14	0.80
36	402796.80	4369612.60	13.7	H07	402796.98	4369612.83	0.29
37	402799.00	4369615.20	13.7	G06	402798.57	4369615.20	0.43
38	402777.80	4369612.80	13.2	F14	402777.51	4369613.29	0.57
39	402776.80	4369616.60	12.4	D14	402776.88	4369617.12	0.53
40	402801.80	4369609.20	12.2	J05	402801.62	4369609.66	0.49
41	402805.80	4369610.00	11.9	J03	402805.56	4369610.40	0.47
42	402805.00	4369613.60	11.7	H03	402804.86	4369614.29	0.70
43	402785.60	4369614.40	10.5	F12	402785.44	4369614.77	0.40
44	402796.80	4369611.20	10.3	I07	402797.32	4369610.97	0.57
45	402797.80	4369608.80	10.3	J07	402797.87	4369608.79	0.07
46	402798.80	4369621.40	9.9				
47	402796.80	4369623.00	9.4	C06	402797.14	4369623.09	0.35
48	402805.80	4369608.00	9.3	K03	402805.92	4369608.42	0.44
49	402786.80	4369606.40	9.1	J12	402786.91	4369606.98	0.59
50	402800.00	4369619.40	9	E05	402799.80	4369619.50	0.22
51	402799.60	4369621.40	8.9	D05	402799.43	4369621.48	0.19
52	402794.80	4369622.60	8.7	C07	402795.19	4369622.72	0.41
53	402802.80	4369603.40	8.2	M05	402802.76	4369603.81	0.41
54	402802.80	4369623.60	7.6	C03	402803.04	4369624.15	0.60
55	402809.80	4369610.80	6.6	J01	402809.53	4369611.13	0.43
56	402777.80	4369609.00	6.5	H14	402778.33	4369609.36	0.64
57	402797.00	4369625.20	6.4	B06	402796.75	4369625.06	0.29
58	402782.00	4369609.60	6.3	H13	402782.23	4369610.10	0.55
59	402800.80	4369623.80	6.3	C04	402801.06	4369623.77	0.26
60	402780.80	4369617.80	6	D13	402780.84	4369618.10	0.30
61	402794.80	4369624.80	5.8	B07	402794.78	4369624.69	0.11
62	402779.80	4369621.20	5.5	B13	402780.07	4369621.92	0.77
63	402800.80	4369625.60	5.3	B04	402800.70	4369625.73	0.16
64	402796.80	4369621.00	5.1	D06	402797.44	4369621.11	0.65
65	402787.00	4369602.60	4.9	L12	402787.47	4369603.01	0.62
66	402800.00	4369617.60	4.8	F05	402800.16	4369617.52	0.18

67	402800.00	4369627.60	4.7	A04	402800.30	4369627.71	0.32
68	402795.80	4369626.80	4.6	A06	402796.33	4369626.99	0.56
69	402804.80	4369612.20	4.4	I03	402805.20	4369612.37	0.43
70	402781.80	4369613.60	4.2	F13	402781.48	4369614.12	0.61
71	402802.20	4369605.40	4	L05	402802.35	4369605.75	0.38
72	402803.60	4369607.60	3.9	K04	402804.00	4369608.02	0.58
73	402806.80	4369622.40	3.9	D01	402807.35	4369622.88	0.73
74	402808.80	4369611.20	3.9				
75	402801.80	4369617.60	3.4	F04	402802.17	4369617.87	0.46
76	402801.60	4369619.20	3.3	E04	402801.77	4369619.85	0.67
77	402803.80	4369620.00	3.3	E03	402803.77	4369620.22	0.22
78	402794.00	4369626.50	2.9	A07	402794.43	4369626.67	0.46
79	402787.00	4369619.00	2.8	D11	402787.59	4369619.34	0.68
80	402798.80	4369613.40	2.6	H06	402798.95	4369613.28	0.19
81	402801.80	4369621.40	2.6	D04	402801.41	4369621.82	0.57
82	402799.00	4369611.20	2.5	I06	402799.31	4369611.32	0.33
83	402803.80	4369609.40	2.4	J04	402803.61	4369610.01	0.64
84	402802.80	4369626.00	2.1	B03	402802.63	4369626.12	0.21
85	402802.00	4369627.20	1.7	A03	402802.29	4369628.07	0.92
86	402808.80	4369619.20	1.7	F01	402808.02	4369618.99	0.81

Man-portable EM61MK2, 5/18/07, Grid NS
Notes: complete, CH3 and CHTop noisy, Vel & data point sep zeros- many times 2 readings in a row have same XY value- GPS set at 10hz
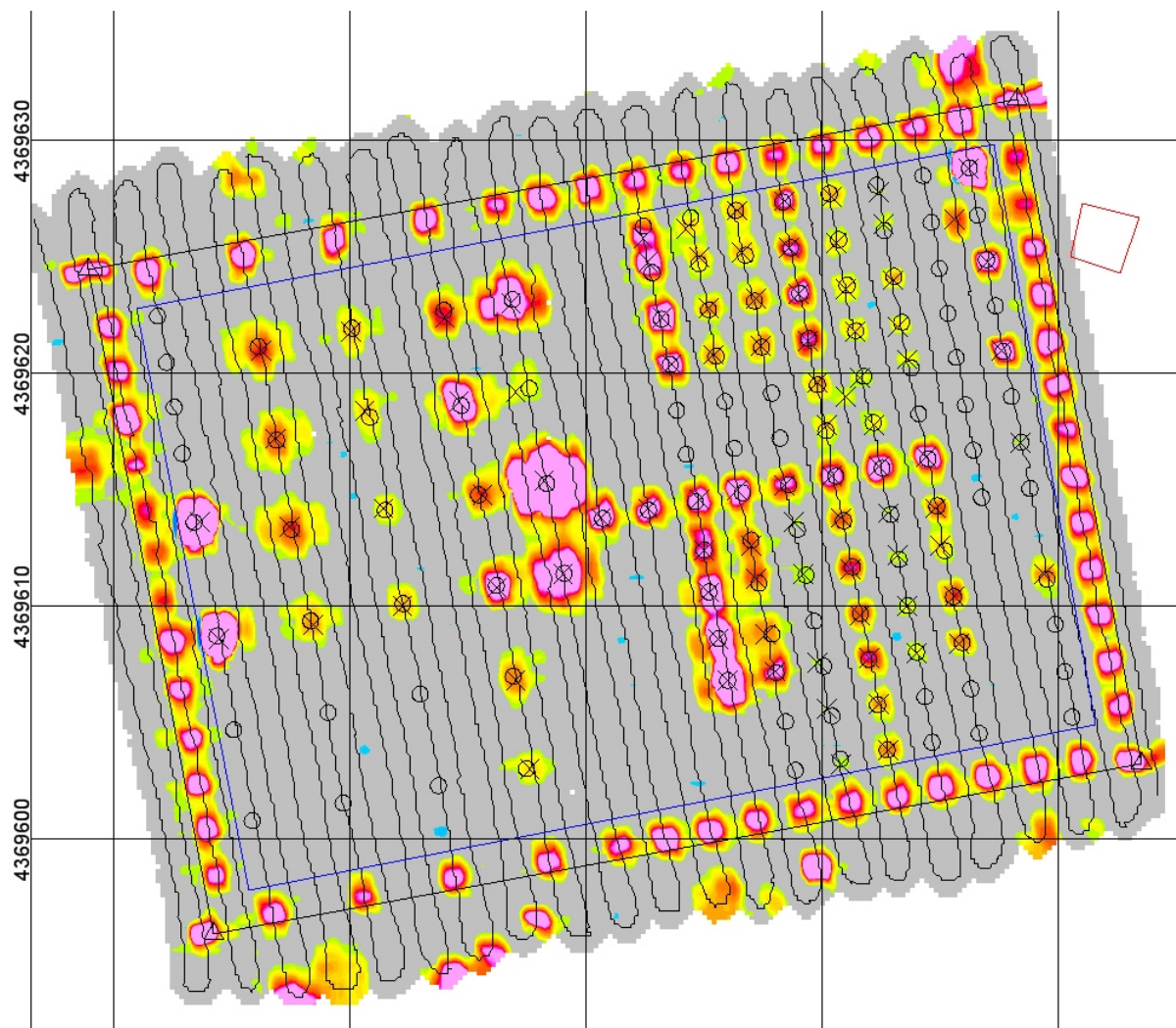
Dig Sheet:

90 of 128 seed items found
1 extra picks
Avg offset dist: 0.18m

Target_ID	x	y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.60	4369613.60	733.4	F15	402773.39	4369613.59	0.21
2	402774.40	4369608.60	663.4	H15	402774.35	4369608.71	0.12
3	402788.20	4369615.40	353.8	F11	402788.33	4369615.26	0.19
4	402806.20	4369628.80	274.7	A01	402806.2	4369628.8	0.03
5	402796.00	4369606.80	92.7	K08	402796.00	4369606.80	0.00
6	402795.60	4369608.60	50.2	J08	402795.60	4369608.60	0.00
7	402784.60	4369618.80	44.2	D12	402784.71	4369618.61	0.22
8	402786.80	4369623.00	42.0	B11	402786.88	4369623.16	0.18
9	402789.00	4369611.40	36.9	H11	402789.06	4369611.40	0.06
10	402793.20	4369622.40	36.9	C08	402793.19	4369622.32	0.08
11	402796.40	4369615.00	35.3	G07	402796.62	4369614.85	0.27

12	402795.20	4369610.60	33.5	I08	402795.20	4369610.60	0.00
13	402786.20	4369610.80	31.3	H12	402786.20	4369610.89	0.09
14	402804.40	4369616.40	30.9	G03	402804.5	4369616.3	0.13
15	402790.60	4369613.80	30.3	G10	402790.70	4369613.75	0.11
16	402807.00	4369624.80	29.3	C01	402807	4369624.9	0.08
17	402802.40	4369616.00	28.4	G04	402802.5	4369615.9	0.16
18	402792.60	4369624.80	27.2	B08	402792.80	4369624.31	0.53
19	402794.80	4369614.60	25.4	G08	402794.62	4369614.48	0.22
20	402793.60	4369620.40	25.2	D08	402793.56	4369620.36	0.06
21	402792.60	4369614.20	24.9	G09	402792.64	4369614.11	0.10
22	402807.60	4369621.00	24.7	E01	402807.7	4369620.9	0.09
23	402800.40	4369615.60	23.5	G05	402800.57	4369615.58	0.17
24	402799.00	4369623.40	22.9	C05	402799.05	4369623.43	0.06
25	402798.40	4369627.40	21.7	A05	402798.32	4369627.35	0.09
26	402792.40	4369625.80	20.9	A08	402792.43	4369626.30	0.50
27	402798.00	4369607.20	19.7	K07	402798.05	4369607.13	0.09
28	402798.40	4369615.20	19.4	G06	402798.57	4369615.20	0.17
29	402795.00	4369612.40	18.9	H08	402795.00	4369612.40	0.00
30	402798.60	4369625.40	18.7	B05	402798.67	4369625.38	0.07
31	402799.40	4369621.40	17.7	D05	402799.43	4369621.48	0.09
32	402802.00	4369607.80	16.6	K05	402802	4369607.7	0.10
33	402801.20	4369611.60	16.5	I05	402801.3	4369611.7	0.10
34	402776.20	4369621.00	14.2	B14	402776.10	4369621.14	0.17
35	402805.60	4369610.40	14.2	J03	402805.6	4369610.4	0.04
36	402785.60	4369614.80	13.8	F12	402785.44	4369614.77	0.16
37	402784.00	4369622.40	13.7	B12	402783.97	4369622.69	0.29
38	402777.40	4369613.40	13.5	F14	402777.51	4369613.29	0.16
39	402797.20	4369611.20	12.9	I07	402797.32	4369610.97	0.26
40	402797.00	4369612.60	12.3	H07	402796.98	4369612.83	0.23
41	402801.60	4369609.60	12.3	J05	402801.6	4369609.7	0.06
42	402805.60	4369626.60	11.2	B01	402806.6	4369626.8	1.00
43	402804.80	4369614.20	11.1	H03	402804.9	4369614.3	0.11
44	402800.80	4369613.80	11.0	H05	402800.90	4369613.66	0.17
45	402776.80	4369617.20	10.7	D14	402776.88	4369617.12	0.11
46	402797.20	4369623.20	9.7	C06	402797.14	4369623.09	0.13
47	402795.20	4369622.80	9.5	C07	402795.19	4369622.72	0.08
48	402787.00	4369606.80	9.4	J12	402786.91	4369606.98	0.20
49	402809.40	4369611.40	9.3	J01	402809.5	4369611.1	0.30
50	402797.60	4369608.80	9.1	J07	402797.87	4369608.79	0.27
51	402802.80	4369603.80	9.1	M05	402802.8	4369603.8	0.04
52	402805.80	4369608.40	8.8	K03	402805.9	4369608.4	0.12
53	402799.80	4369619.60	8.3	E05	402799.80	4369619.50	0.10
54	402795.40	4369620.80	8.2	D07	402795.50	4369620.73	0.12
55	402797.40	4369621.20	8.2	D06	402797.44	4369621.11	0.10
56	402802.40	4369605.80	8.2	L05	402802.4	4369605.8	0.07
57	402778.40	4369609.20	7.8	H14	402778.33	4369609.36	0.17
58	402796.40	4369627.00	7.8	A06	402796.33	4369626.99	0.07
59	402794.80	4369625.00	7.7	B07	402794.78	4369624.69	0.31
60	402803.00	4369624.00	7.5	C03	402803	4369624.2	0.16
61	402800.40	4369627.60	6.9	A04	402800.30	4369627.71	0.15
62	402796.60	4369625.20	6.8	B06	402796.75	4369625.06	0.21
63	402782.20	4369610.00	6.5	H13	402782.23	4369610.10	0.10
64	402780.00	4369621.80	6.4	B13	402780.07	4369621.92	0.14

65	402800.20	4369617.80	6.4	F05	402800.16	4369617.52	0.28
66	402780.60	4369618.40	6.1	D13	402780.84	4369618.10	0.38
67	402805.00	4369612.60	6.1	I03	402805.2	4369612.4	0.30
68	402794.20	4369626.20	6.0	A07	402794.43	4369626.67	0.52
69	402801.40	4369621.80	5.4	D04	402801.4	4369621.8	0.02
70	402800.60	4369625.60	5.3	B04	402800.70	4369625.73	0.16
71	402787.60	4369603.00	5.2	L12	402787.47	4369603.01	0.13
72	402803.20	4369622.00	5.2	D03	402803.4	4369622.2	0.25
73	402781.40	4369614.20	4.7	F13	402781.48	4369614.12	0.11
74	402801.00	4369623.60	4.5	C04	402801.1	4369623.8	0.18
75	402802.20	4369617.80	4.4	F04	402802.2	4369617.9	0.08
76	402803.60	4369620.60	3.7	E03	402803.8	4369620.2	0.42
77	402803.60	4369610.00	3.5	J04	402803.6	4369610	0.01
78	402802.60	4369626.40	3.4	B03	402802.6	4369626.1	0.28
79	402801.00	4369619.00	3.2				
80	402787.00	4369619.20	3.1	D11	402787.59	4369619.34	0.61
81	402801.60	4369619.80	3.1	E04	402801.8	4369619.9	0.18
82	402803.20	4369612.20	2.5	I04	402803.3	4369612	0.21
83	402804.00	4369608.00	2.5	K04	402804	4369608	0.02
84	402800.80	4369603.20	2.0	M06	402800.77	4369603.42	0.22
85	402802.80	4369614.00	1.9	H04	402802.9	4369613.9	0.12
86	402798.80	4369613.60	1.8	H06	402798.95	4369613.28	0.35
87	402799.80	4369607.60	1.8	K06	402800.07	4369607.41	0.33
88	402802.40	4369627.80	1.8	A03	402802.3	4369628.1	0.29
89	402808.40	4369617.00	1.8	G01	402808.4	4369617	0.04
90	402799.20	4369611.40	1.7	I06	402799.31	4369611.32	0.14
91	402800.20	4369605.60	1.5	L06	402800.41	4369605.27	0.39

Man-portable EM61MK2, 5/21/07, Grid NS

Notes: complete but line spacing not even (too close, too far, etc), noisy, 1hz spikes (pos on Ch1, neg on Ch2); GPS set to 10Hz- not getting consistent sampling rate (sometimes 6hz, 8hz,10hz)- data collector couldn't keep up with 10Hz GPS & data sampling at this speed & dropped multiple readings
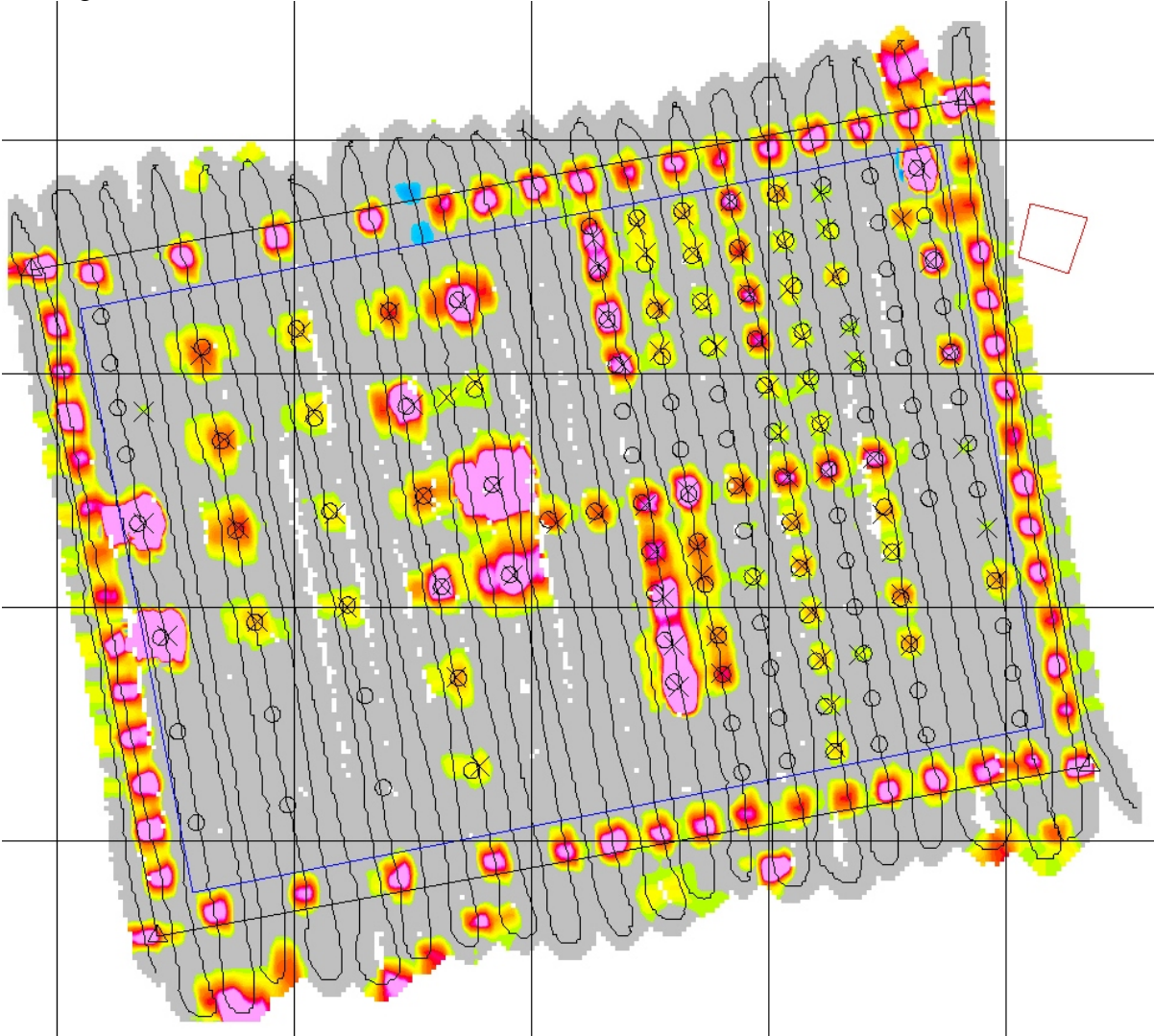
Dig Sheet:

83 of 128 seed items found
3 extra picks
Avg offset dist: 0.23m

Target_ID	x	y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.60	4369613.60	641.0	F15	402773.4	4369613.6	0.21
2	402774.60	4369608.80	582.6	H15	402774.4	4369608.7	0.27
3	402788.40	4369615.20	311.7	F11	402788.3	4369615.3	0.09
4	402806.40	4369628.80	202.6	A01	402806.2	4369628.8	0.17
5	402796.20	4369606.60	76.9	K08	402796	4369606.8	0.28
6	402796.00	4369608.40	41.9	J08	402795.6	4369608.6	0.45
7	402785.00	4369618.70	38.2	D12	402784.7	4369618.6	0.30
8	402787.00	4369623.00	34.8	B11	402786.9	4369623.2	0.20

9	402789.20	4369611.40	33.9	H11	402789.1	4369611.4	0.14
10	402786.20	4369611.00	32.6	H12	402786.2	4369610.9	0.11
11	402793.20	4369622.40	32.4	C08	402793.2	4369622.3	0.08
12	402796.60	4369615.00	31.0	G07	402796.6	4369614.9	0.15
13	402806.80	4369624.80	29.6	C01	402807	4369624.9	0.17
14	402795.60	4369610.40	29.2	I08	402795.2	4369610.6	0.45
15	402792.60	4369625.80	22.3	A08	402792.4	4369626.3	0.53
16	402792.80	4369624.60	22.0	B08	402792.8	4369624.3	0.29
17	402807.60	4369620.80	21.9	E01	402807.7	4369620.9	0.14
18	402793.80	4369620.40	21.3	D08	402793.6	4369620.4	0.24
19	402802.40	4369615.80	20.9	G04	402802.5	4369615.9	0.18
20	402804.40	4369616.40	20.6	G03	402804.5	4369616.3	0.13
21	402798.40	4369627.40	19.3	A05	402798.3	4369627.4	0.09
22	402799.20	4369623.40	18.2	C05	402799.1	4369623.4	0.15
23	402800.80	4369615.60	17.6	G05	402800.6	4369615.6	0.23
24	402794.80	4369614.40	17.2	G08	402794.6	4369614.5	0.20
25	402799.60	4369621.40	16.7	D05	402799.4	4369621.5	0.19
26	402795.20	4369612.40	16.2	H08	402795	4369612.4	0.20
27	402798.00	4369607.20	15.3	K07	402798.1	4369607.1	0.09
28	402798.80	4369625.20	14.6	B05	402798.7	4369625.4	0.22
29	402784.00	4369622.60	13.8	B12	402784	4369622.7	0.09
30	402777.60	4369613.40	13.2	F14	402777.5	4369613.3	0.14
31	402791.00	4369613.60	13.0	G10	402790.7	4369613.8	0.34
32	402798.80	4369615.20	12.3	G06	402798.6	4369615.2	0.23
33	402797.00	4369612.60	12.2	H07	402797	4369612.8	0.23
34	402776.00	4369620.80	11.8	B14	402776.1	4369621.1	0.35
35	402792.80	4369614.00	11.4	G09	402792.6	4369614.1	0.19
36	402777.00	4369617.20	10.8	D14	402776.9	4369617.1	0.14
37	402785.40	4369614.80	10.3	F12	402785.4	4369614.8	0.05
38	402805.60	4369610.60	9.9	J03	402805.6	4369610.4	0.20
39	402797.20	4369611.40	9.8	I07	402797.3	4369611	0.45
40	402805.60	4369626.60	9.3	B01	402806.6	4369626.8	1.00
41	402797.80	4369608.80	8.7	J07	402797.9	4369608.8	0.07
42	402795.40	4369622.80	8.6	C07	402795.2	4369622.7	0.22
43	402801.40	4369611.80	8.2	I05	402801.3	4369611.7	0.18
44	402801.00	4369613.60	8.0	H05	402800.9	4369613.7	0.12
45	402800.40	4369627.80	7.8	A04	402800.3	4369627.7	0.13
46	402806.00	4369608.40	7.6	K03	402805.9	4369608.4	0.08
47	402809.60	4369611.20	7.4	J01	402809.5	4369611.1	0.10
48	402801.80	4369609.80	7.3	J05	402801.6	4369609.7	0.23
49	402804.80	4369614.00	7.3	H03	402804.9	4369614.3	0.30
50	402786.80	4369607.00	7.2	J12	402786.9	4369607	0.11
51	402778.40	4369609.40	6.6	H14	402778.3	4369609.4	0.08
52	402802.80	4369624.20	6.5	C03	402803	4369624.2	0.25
53	402796.40	4369626.80	6.4	A06	402796.3	4369627	0.20
54	402802.20	4369607.80	6.2	K05	402802	4369607.7	0.25
55	402795.40	4369621.00	5.9	D07	402795.5	4369620.7	0.29
56	402780.20	4369621.80	5.7	B13	402780.1	4369621.9	0.18
57	402802.80	4369604.00	5.4	M05	402802.8	4369603.8	0.19
58	402780.80	4369618.40	5.0	D13	402780.8	4369618.1	0.30
59	402782.20	4369610.00	5.0	H13	402782.2	4369610.1	0.10
60	402800.80	4369623.60	4.9	C04	402801.1	4369623.8	0.31
61	402794.40	4369626.40	4.8	A07	402794.4	4369626.7	0.27

62	402800.00	4369619.40	4.8	E05	402799.8	4369619.5	0.22
63	402781.70	4369614.00	4.8	F13	402781.5	4369614.1	0.25
64	402800.60	4369625.60	4.7	B04	402800.7	4369625.7	0.16
65	402796.80	4369625.20	4.6	B06	402796.8	4369625.1	0.15
66	402787.80	4369603.20	4.5	L12	402787.5	4369603	0.38
67	402794.80	4369625.20	4.5	B07	402794.8	4369624.7	0.51
68	402797.80	4369621.20	4.5	D06	402797.4	4369621.1	0.37
69	402797.20	4369623.00	4.1	C06	402797.1	4369623.1	0.11
70	402801.40	4369621.60	4.0	D04	402801.4	4369621.8	0.22
71	402802.20	4369617.80	3.9	F04	402802.2	4369617.9	0.08
72	402805.20	4369612.40	3.8	I03	402805.2	4369612.4	0.03
73	402787.60	4369619.60	3.7	D11	402787.6	4369619.3	0.26
74	402802.60	4369605.80	3.7	L05	402802.4	4369605.8	0.25
75	402799.40	4369611.20	3.1	I06	402799.3	4369611.3	0.15
76	402800.40	4369617.40	2.9	F05	402800.2	4369617.5	0.27
77	402801.60	4369619.60	2.9	E04	402801.8	4369619.9	0.30
78	402802.40	4369626.20	2.9	B03	402802.6	4369626.1	0.24
79	402803.80	4369608.00	2.7	K04	402804	4369608	0.20
80	402786.40	4369619.00	2.5				
81	402802.20	4369627.80	2.4	A03	402802.3	4369628.1	0.28
82	402803.60	4369620.60	2.3	E03	402803.8	4369620.2	0.42
83	402808.20	4369616.80	2.1	G01	402808.4	4369617	0.32
84	402803.40	4369622.00	1.9	D03	402803.4	4369622.2	0.18
85	402773.60	4369618.40	1.8				
86	402809.20	4369613.40	1.8				

Man-portable EM61MK2, Fiducial Positioning, 5/14/07, Grid EW
Notes: Some missing fids, line 27 incomplete, had to estimate the last line position (not to/from known points), latency correction makes most lines better & some worse- tried multiple values to get best one.
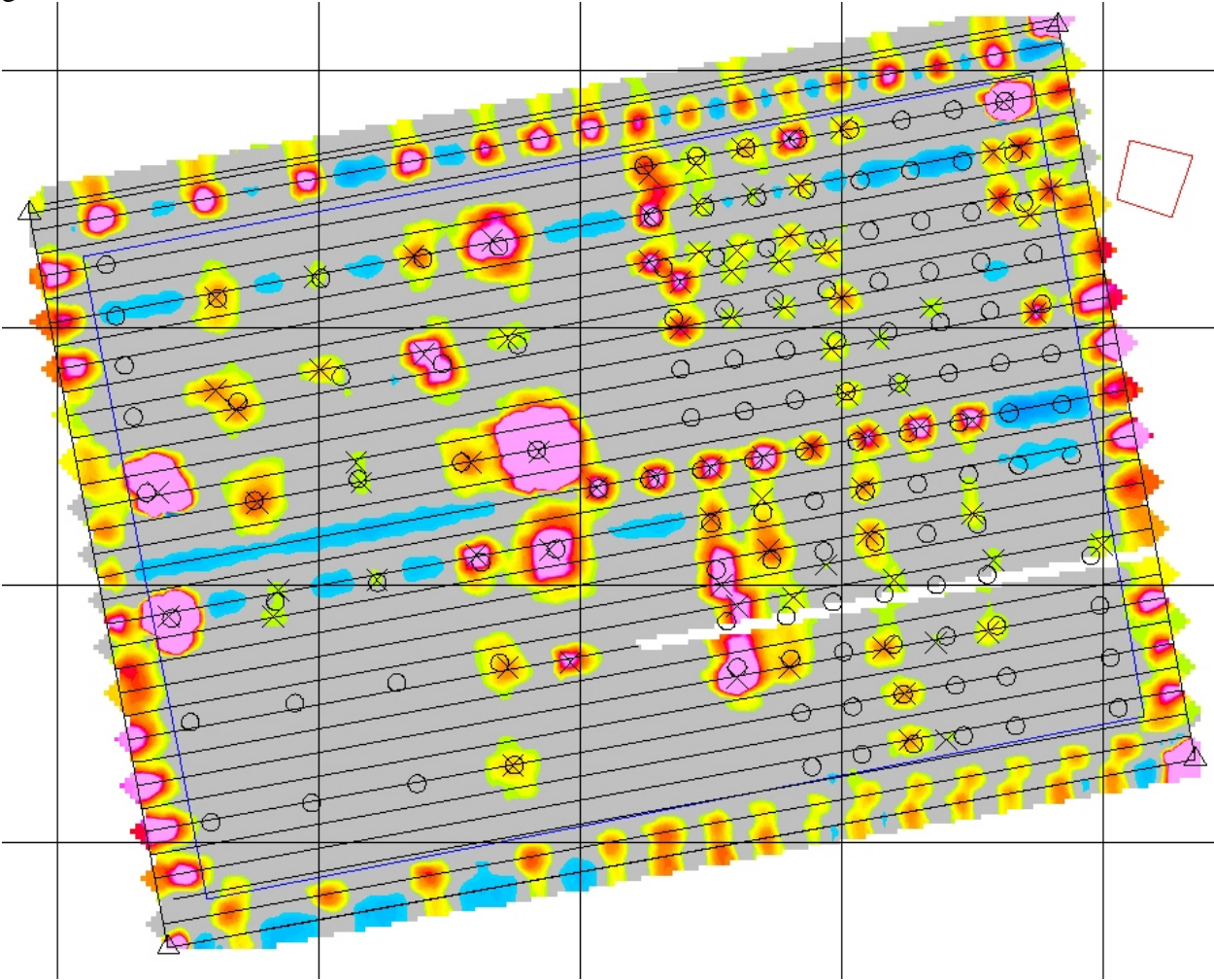
Dig Sheet:

75 of 128 seed items found

11 extra picks

Avg offset dist: 0.39m

note: cannot get good latency/lag correction; some chevrons get better while others get worse; chose best one (lag -4)

some extra picks from chevrons

Target_ID	x	y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.80	4369613.60	615.4	F15	402773.39	4369613.59	0.41
2	402774.20	4369608.80	553.5	H15	402774.35	4369608.71	0.17
3	402788.40	4369615.20	345.4	F11	402788.33	4369615.26	0.09
4	402806.20	4369628.80	251.7	A01	402806.23	4369628.81	0.03
5	402796.00	4369606.40	62.2	K08	402796.00	4369606.80	0.40
6	402786.60	4369623.40	36.3	B11	402786.88	4369623.16	0.37
7	402788.80	4369611.40	31.7	H11	402789.06	4369611.40	0.26
8	402784.00	4369619.00	30.1	D12	402784.71	4369618.61	0.81
9	402797.00	4369615.00	29.3	G07	402796.62	4369614.85	0.41
10	402795.40	4369610.00	28.1	I08	402795.20	4369610.60	0.63
11	402786.00	4369611.20	27.1	H12	402786.20	4369610.89	0.37

12	402803.00	4369616.20	25.8	G04	402802.54	4369615.92	0.54
13	402792.60	4369624.40	24.7	B08	402792.80	4369624.31	0.22
14	402798.00	4369627.40	23.7	A05	402798.32	4369627.35	0.32
15	402805.00	4369616.40	21.8	G03	402804.49	4369616.31	0.52
16	402792.80	4369614.20	21.6	G09	402792.64	4369614.11	0.18
17	402795.00	4369614.60	21.3	G08	402794.62	4369614.48	0.40
18	402796.00	4369609.20	21.3	J08	402795.60	4369608.60	0.72
19	402790.60	4369613.80	20.5	G10	402790.70	4369613.75	0.11
20	402792.60	4369622.60	20.1	C08	402793.19	4369622.32	0.65
21	402801.00	4369615.80	19.3	G05	402800.57	4369615.58	0.48
22	402807.40	4369620.60	18.6	E01	402807.66	4369620.93	0.42
23	402793.80	4369621.80	18.5				
24	402789.60	4369607.00	18.4				
25	402793.80	4369620.00	15.7	D08	402793.56	4369620.36	0.43
26	402806.00	4369625.00	14.4				
27	402808.00	4369625.40	14.3				
28	402798.80	4369615.40	13.9	G06	402798.57	4369615.20	0.30
29	402806.80	4369627.00	12.9	B01	402806.58	4369626.78	0.31
30	402797.20	4369611.40	12.8	I07	402797.32	4369610.97	0.45
31	402792.60	4369626.00	12.4	A08	402792.43	4369626.30	0.34
32	402777.60	4369613.20	11.6	F14	402777.51	4369613.29	0.13
33	402783.60	4369622.80	11.1	B12	402783.97	4369622.69	0.39
34	402795.00	4369612.60	11.0	H08	402795.00	4369612.40	0.20
35	402785.80	4369614.80	10.4	F12	402785.44	4369614.77	0.36
36	402787.20	4369606.80	9.4	J12	402786.91	4369606.98	0.34
37	402801.60	4369607.60	9.3	K05	402801.97	4369607.70	0.38
38	402800.00	4369621.20	9.3	D05	402799.43	4369621.48	0.64
39	402776.80	4369616.80	8.6	D14	402776.88	4369617.12	0.33
40	402800.80	4369613.80	8.4	H05	402800.90	4369613.66	0.17
41	402805.80	4369626.80	8.4				
42	402776.00	4369617.60	8.4				
43	402798.00	4369606.80	8.4	K07	402798.05	4369607.13	0.33
44	402801.00	4369612.00	8.3	I05	402801.27	4369611.67	0.43
45	402802.60	4369604.00	8.0	M05	402802.76	4369603.81	0.25
46	402776.00	4369621.20	7.8	B14	402776.10	4369621.14	0.12
47	402802.40	4369605.80	7.7	L05	402802.35	4369605.75	0.07
48	402800.00	4369627.80	7.6	A04	402800.30	4369627.71	0.31
49	402798.00	4369623.60	7.1				
50	402798.40	4369625.60	7.1	B05	402798.67	4369625.38	0.35
51	402796.20	4369627.00	7.0	A06	402796.33	4369626.99	0.13
52	402807.20	4369624.40	6.8	C01	402806.96	4369624.87	0.53
53	402787.40	4369603.00	6.3	L12	402787.47	4369603.01	0.07
54	402799.40	4369623.00	6.2	C05	402799.05	4369623.43	0.55
55	402780.00	4369618.40	6.1	D13	402780.84	4369618.10	0.89
56	402805.60	4369608.20	4.7	K03	402805.92	4369608.42	0.39
57	402800.20	4369617.40	4.7	F05	402800.16	4369617.52	0.13
58	402799.60	4369619.20	4.2	E05	402799.80	4369619.50	0.36
59	402796.93	4369613.36	3.9	H07	402796.98	4369612.83	0.53
60	402805.00	4369612.80	3.8	I03	402805.20	4369612.37	0.47
61	402796.00	4369623.00	3.7				
62	402794.51	4369622.99	3.6	C07	402795.19	4369622.72	0.73
63	402794.60	4369624.80	3.5	B07	402794.78	4369624.69	0.21
64	402794.40	4369626.40	3.5	A07	402794.43	4369626.67	0.27

65	402797.80	4369620.80	3.4	D06	402797.44	4369621.11	0.48
66	402797.60	4369622.60	3.3	C06	402797.14	4369623.09	0.67
67	402795.80	4369622.20	3.1				
68	402795.80	4369620.40	3.1	D07	402795.50	4369620.73	0.45
69	402798.15	4369609.53	3.0	J07	402797.87	4369608.79	0.79
70	402787.20	4369619.60	2.7	D11	402787.59	4369619.34	0.47
71	402809.92	4369611.58	2.7	J01	402809.53	4369611.13	0.60
72	402779.80	4369622.00	2.7	B13	402780.07	4369621.92	0.28
73	402802.00	4369610.20	2.6	J05	402801.62	4369609.66	0.66
74	402781.60	4369614.00	2.6	F13	402781.48	4369614.12	0.17
75	402778.20	4369608.80	2.5				
76	402802.20	4369617.80	2.4	F04	402802.17	4369617.87	0.08
77	402803.40	4369620.80	2.3	E03	402803.77	4369620.22	0.69
78	402796.60	4369625.20	2.3	B06	402796.75	4369625.06	0.21
79	402782.20	4369610.20	2.2	H13	402782.23	4369610.10	0.10
80	402778.40	4369609.80	2.2	H14	402778.33	4369609.36	0.45
81	402801.40	4369619.60	2.0	E04	402801.77	4369619.85	0.45
82	402781.40	4369614.80	1.9				
83	402805.80	4369611.00	1.9	J03	402805.56	4369610.40	0.65
84	402799.40	4369610.80	1.7	I06	402799.31	4369611.32	0.53
85	402803.60	4369607.80	1.6	K04	402804.00	4369608.02	0.46
86	402804.00	4369604.00	1.5	M04	402804.66	4369604.14	0.67

Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

XT (Manned Segway) Towed EM61MK2, 5/21/07, Grid NS
Notes: Bad GPS coverage (quality) for part of the grid (one gap ~8m); noisy, 1hz spikes (pos on Ch1, neg on Ch2); GPS set to 10Hz- not getting consistent sampling rate (sometimes 8hz,9hz)- data collector couldn't keep up with 10Hz GPS & data sampling at this speed & dropped multiple readings- leading to zero velocity, then the next point velocity very high
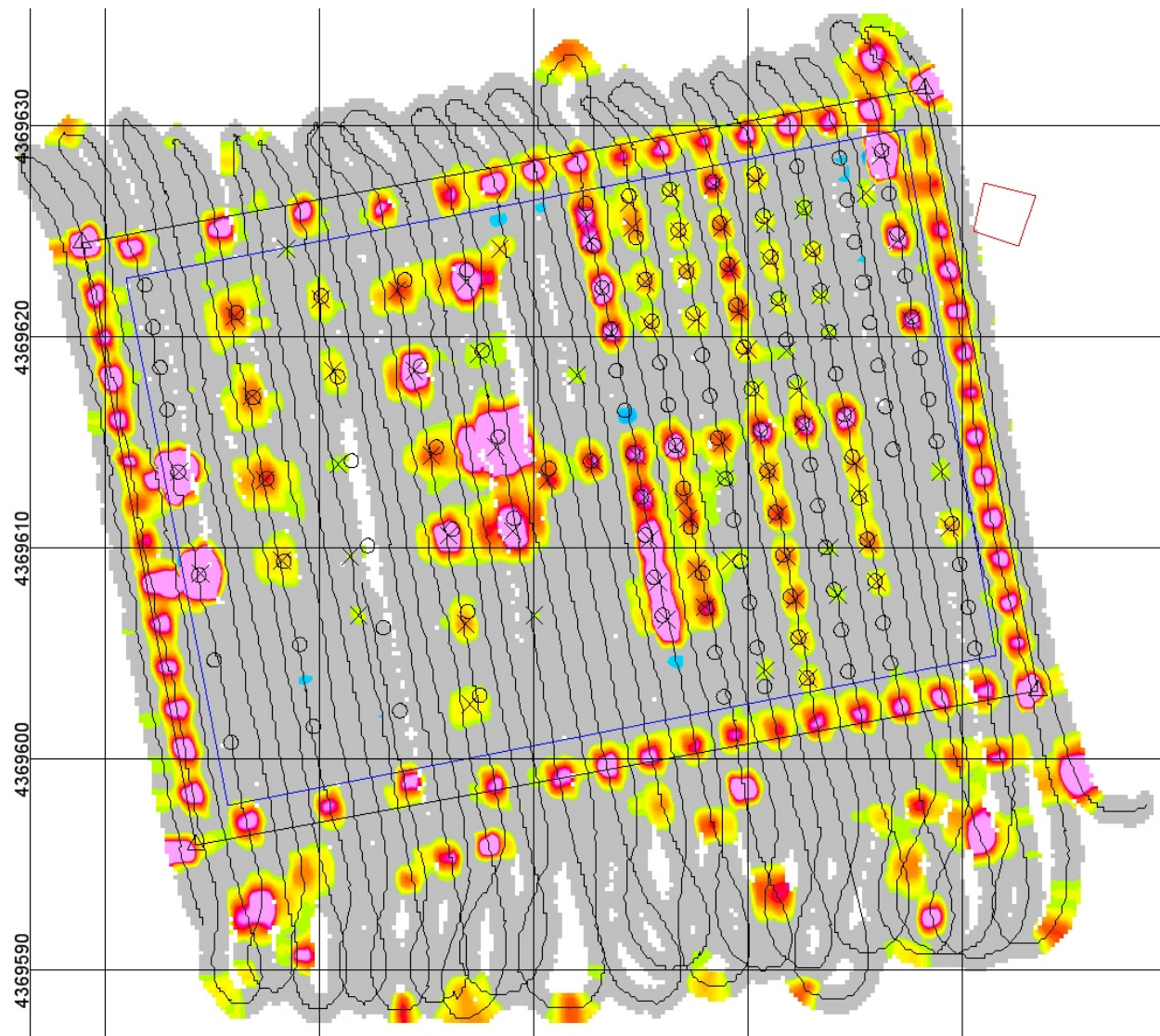
Dig Sheet:

84 of 128 seed items found note: some bad GPS, drop-outs and non-RTK Fix data
6 extra
picks
Avg offset dist: 0.29m

Target_ID	x	y	ch3	SeedMatched	SeedX	SeedY	Offset
1	402773.40	4369613.60	580.2	F15	402773.39	4369613.59	0.01
2	402774.40	4369608.80	475.5	H15	402774.35	4369608.71	0.10
3	402788.20	4369614.80	322.1	F11	402788.33	4369615.26	0.48
4	402806.20	4369628.60	178.2	A01	402806.23	4369628.81	0.21
5	402796.20	4369606.60	76.5	K08	402796.00	4369606.80	0.28

6	402795.80	4369608.40	41.4 J08	402795.60	4369608.60	0.28
7	402784.40	4369618.40	38.8 D12	402784.71	4369618.61	0.37
8	402786.00	4369610.60	37.3 H12	402786.20	4369610.89	0.35
9	402796.60	4369614.80	33.9 G07	402796.62	4369614.85	0.05
10	402793.20	4369622.20	32.4 C08	402793.19	4369622.32	0.12
11	402789.00	4369610.80	30.7 H11	402789.06	4369611.40	0.60
12	402786.80	4369622.60	30.2 B11	402786.88	4369623.16	0.57
13	402795.40	4369610.40	27.4 I08	402795.20	4369610.60	0.28
14	402804.60	4369616.20	22.9 G03	402804.49	4369616.31	0.16
15	402807.00	4369624.60	22.8 C01	402806.96	4369624.87	0.27
16	402793.60	4369620.20	21.0 D08	402793.56	4369620.36	0.16
17	402792.60	4369624.60	19.7 B08	402792.80	4369624.31	0.35
18	402800.60	4369615.40	19.7 G05	402800.57	4369615.58	0.18
19	402802.60	4369615.80	19.5 G04	402802.54	4369615.92	0.13
20	402807.60	4369620.80	18.9 E01	402807.66	4369620.93	0.14
21	402792.40	4369625.60	18.7 A08	402792.43	4369626.30	0.70
22	402794.80	4369614.40	18.7 G08	402794.62	4369614.48	0.20
23	402795.20	4369612.40	18.5 H08	402795.00	4369612.40	0.20
24	402792.80	4369614.00	17.9 G09	402792.64	4369614.11	0.19
25	402798.40	4369627.20	17.9 A05	402798.32	4369627.35	0.17
26	402799.20	4369623.20	15.3 C05	402799.05	4369623.43	0.27
27	402798.00	4369607.20	14.7 K07	402798.05	4369607.13	0.09
28	402783.60	4369622.20	13.8 B12	402783.97	4369622.69	0.61
29	402777.40	4369613.20	13.5 F14	402777.51	4369613.29	0.14
30	402799.60	4369621.20	13.5 D05	402799.43	4369621.48	0.33
31	402801.40	4369611.60	13.5 I05	402801.27	4369611.67	0.15
32	402785.20	4369614.40	13.2 F12	402785.44	4369614.77	0.44
33	402790.60	4369613.20	13.2 G10	402790.70	4369613.75	0.56
34	402797.20	4369611.40	13.2 I07	402797.32	4369610.97	0.45
35	402776.00	4369621.00	13.0 B14	402776.10	4369621.14	0.17
36	402798.80	4369615.00	12.3 G06	402798.57	4369615.20	0.30
37	402798.80	4369625.20	11.5 B05	402798.67	4369625.38	0.22
38	402797.00	4369612.20	11.4 H07	402796.98	4369612.83	0.63
39	402802.20	4369607.60	11.2 K05	402801.97	4369607.70	0.25
40	402801.80	4369609.60	10.7 J05	402801.62	4369609.66	0.19
41	402776.80	4369617.20	10.4 D14	402776.88	4369617.12	0.11
42	402797.60	4369609.00	10.3 J07	402797.87	4369608.79	0.34
43	402794.60	4369625.20	10.2 B07	402794.78	4369624.69	0.54
44	402805.60	4369610.20	9.7 J03	402805.56	4369610.40	0.20
45	402801.00	4369613.60	8.8 H05	402800.90	4369613.66	0.12
46	402805.00	4369614.00	8.7 H03	402804.86	4369614.29	0.32
47	402786.80	4369606.40	8.1 J12	402786.91	4369606.98	0.59
48	402797.10	4369623.20	7.0 C06	402797.14	4369623.09	0.12
49	402795.20	4369622.60	6.9 C07	402795.19	4369622.72	0.12
50	402809.40	4369611.00	6.9 J01	402809.53	4369611.13	0.18
51	402800.40	4369627.40	6.5 A04	402800.30	4369627.71	0.33
52	402778.20	4369609.40	6.1 H14	402778.33	4369609.36	0.14
53	402800.00	4369619.40	6.0 E05	402799.80	4369619.50	0.22
54	402802.80	4369603.80	6.0 M05	402802.76	4369603.81	0.04
55	402802.40	4369605.60	5.9 L05	402802.35	4369605.75	0.16
56	402788.40	4369624.20	5.8			
57	402795.40	4369620.60	5.8 D07	402795.50	4369620.73	0.16
58	402780.00	4369621.80	5.6 B13	402780.07	4369621.92	0.14
59	402796.80	4369625.00	5.3 B06	402796.75	4369625.06	0.08

60	402803.00	4369624.00	5.3 C03	402803.04	4369624.15	0.16
61	402794.40	4369626.30	5.2 A07	402794.43	4369626.67	0.37
62	402797.60	4369620.80	5.1 D06	402797.44	4369621.11	0.35
63	402801.00	4369623.60	5.1 C04	402801.06	4369623.77	0.18
64	402800.80	4369625.40	4.9 B04	402800.70	4369625.73	0.34
65	402780.60	4369618.40	4.8 D13	402780.84	4369618.10	0.38
66	402806.00	4369608.40	4.7 K03	402805.92	4369608.42	0.08
67	402796.40	4369626.80	4.6 A06	402796.33	4369626.99	0.20
68	402805.20	4369612.60	4.4 I03	402805.20	4369612.37	0.23
69	402787.00	4369602.60	4.1 L12	402787.47	4369603.01	0.62
70	402799.20	4369609.40	3.4 J06	402799.66	4369609.34	0.46
71	402800.30	4369617.50	3.4 F05	402800.16	4369617.52	0.14
72	402801.40	4369621.60	3.4 D04	402801.41	4369621.82	0.22
73	402802.30	4369617.50	3.4 F04	402802.17	4369617.87	0.39
74	402803.40	4369622.00	3.0 D03	402803.37	4369622.18	0.18
75	402781.80	4369606.80	2.8			
76	402803.80	4369620.20	2.7 E03	402803.77	4369620.22	0.04
77	402800.80	4369604.20	2.6 M06	402800.77	4369603.42	0.78
78	402805.50	4369626.80	2.6 B02	402804.62	4369626.47	0.94
79	402787.40	4369619.20	2.4 D11	402787.59	4369619.34	0.24
80	402802.60	4369626.00	2.4 B03	402802.63	4369626.12	0.12
81	402809.00	4369613.60	2.4			
82	402790.00	4369606.80	2.1			
83	402792.00	4369618.20	2.1			
84	402804.20	4369607.80	2.1 K04	402804.00	4369608.02	0.30
85	402798.90	4369613.30	1.9 H06	402798.95	4369613.28	0.05
86	402778.40	4369624.20	1.8			
87	402803.80	4369610.00	1.8 J04	402803.61	4369610.01	0.19
88	402780.80	4369614.00	1.7 F13	402781.48	4369614.12	0.69
89	402781.40	4369609.60	1.7 H13	402782.23	4369610.10	0.97
90	402801.80	4369619.40	1.6 E04	402801.77	4369619.85	0.45

Geometrics G-858 Magnetometer Surveys: The RMP 400 mapped the Calibration Grid in the grid N-S orientation for two trials on 22 May 2007 using a horizontal array of two G-858 magnetometers at a .5 m spacing. The surveys had a common problem that made them unsuitable for target comparison. We used the hitch angle sensor and a longer (3 m tow bar) to provide robot and sensor separation. This increased tow bar length required a unique path plan using larger turning radius. Also these were the last surveys of the demonstration and we did not have geophysical support to insure data quality. We may have not entered the corrected tow bar length to predict trailer location. This would put reported locations at .67 m closer to the tow vehicle than the sensors. We did not record the robot position data in a manner that we could validate and reprocess trailer locations. Our geophysicist states that the grid should be resurveyed and the data is not usable as follows:

"I've been trying to work with the mag data, and I just can't get the positioning to work out............from a QC perspective, I would just say to recollect. Most of the positions got better when I did a latency correction, but some got worse, and I had to use an extremely high value (0.94s). **(Based upon .75 m/sec velocity this equates to a .7 m offset which supports the theory that we did not change the tow bar length value to calculate trailer position. This can not be easily fixed since we change rotation directions and turning radius when we interleave pathways)** *Some targets look like latency issues even though they are going in the same direction- I don't know what could cause this. My personal opinion is that we shouldn't spend more time on this because we know it isn't good and it will give flawed results for you positioning analysis. I think you have proven that you can collect data with the robot without causing noise/interference, but the positioning with that instrument has not been proven."* An example representation follows:
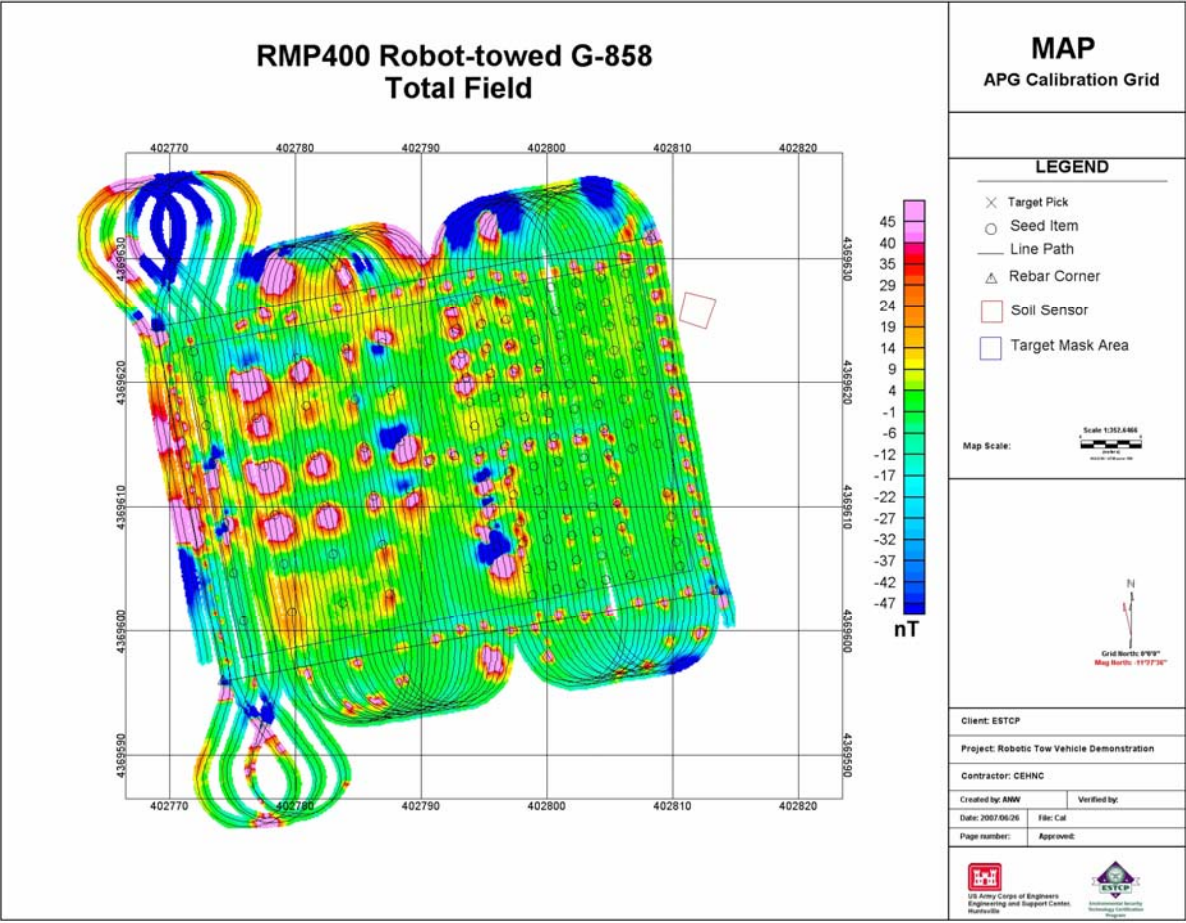
Comparison of Calibration Lane Surveys to the May 2004 Baseline

Calibration Lanes	Total Seed Items 128			from Seeds	from Base-line	from Base-line	from Base-line
	seed picks	Non-Seed Picks	Average offset		% Seeds Picked	Additional picks	Offset change
Baseline: Man-Portable EM61MK2, May 2004, Grid NS	**89**	**2**	**0.2**				
RMP400 Robot-towed EM61MK2 with Hitch Angle Sensor, 5/15/07, Grid NS, Offset from items	80	2	0.53		0.898876	0	0.33
RMP400 Robot-towed EM61MK2 with Hitch Angle Sensor, 5/15/07, True NS	84	6	0.33		0.94382	4	0.13
RMP400 Robot-towed EM61MK2 with Hitch Angle Sensor, 5/15/07, True EW	85	3	0.33		0.955056	1	0.13
RMP400 Robot-towed EM61MK2, 5/18/07, Grid NS	87	1	0.31		0.977528	-1	0.11
RMP400 Robot-towed EM61MK2, 5/18/07, Grid NS, Offset from items	71	6	0.56		0.797753	4	0.36
RMP400 Robot-towed EM61MK2, 5/19/07, Grid EW	78	5	0.34		0.876404	3	0.14
RMP400 Robot-towed EM61MK2, 5/19/07, True EW (merged part 1 & 2)	84	11	0.41		0.94382	9	0.21
RMP400 Robot-towed EM61MK2, 5/19/07, True NS	84	2	0.44		0.94382	0	0.24
Man-portable EM61MK2, 5/18/07, Grid NS	90	1	0.18		1.011236	-1	-0.02
Man-portable EM61MK2, 5/21/07, Grid NS	83	3	0.23		0.932584	1	0.03
Man-portable EM61MK2, Fiducial Positioning, 5/14/07, Grid EW	75	11	0.39		0.842697	9	0.19
XT (Manned Segway) Towed EM61MK2, 5/21/07, Grid NS	84	6	0.29		0.94382	4	0.09

Notes: With the .15 m uncertainty caused by MagLogNT we are not confident in the shown positional results. The average difference in offset for all surveys from the baseline was .16 m with an average of 3 additional picks and 92% of the baseline seeds picked. Our man portable survey performance was slightly better than the baseline.

Open Field Survey

The Open Field area is covered by four grids as shown by the site layout and the composite of geophysical images for Grids 1-4. Grid 5 duplicates a portion of the Grid 1-4 area in an alternate survey orientation (about 30 degrees).
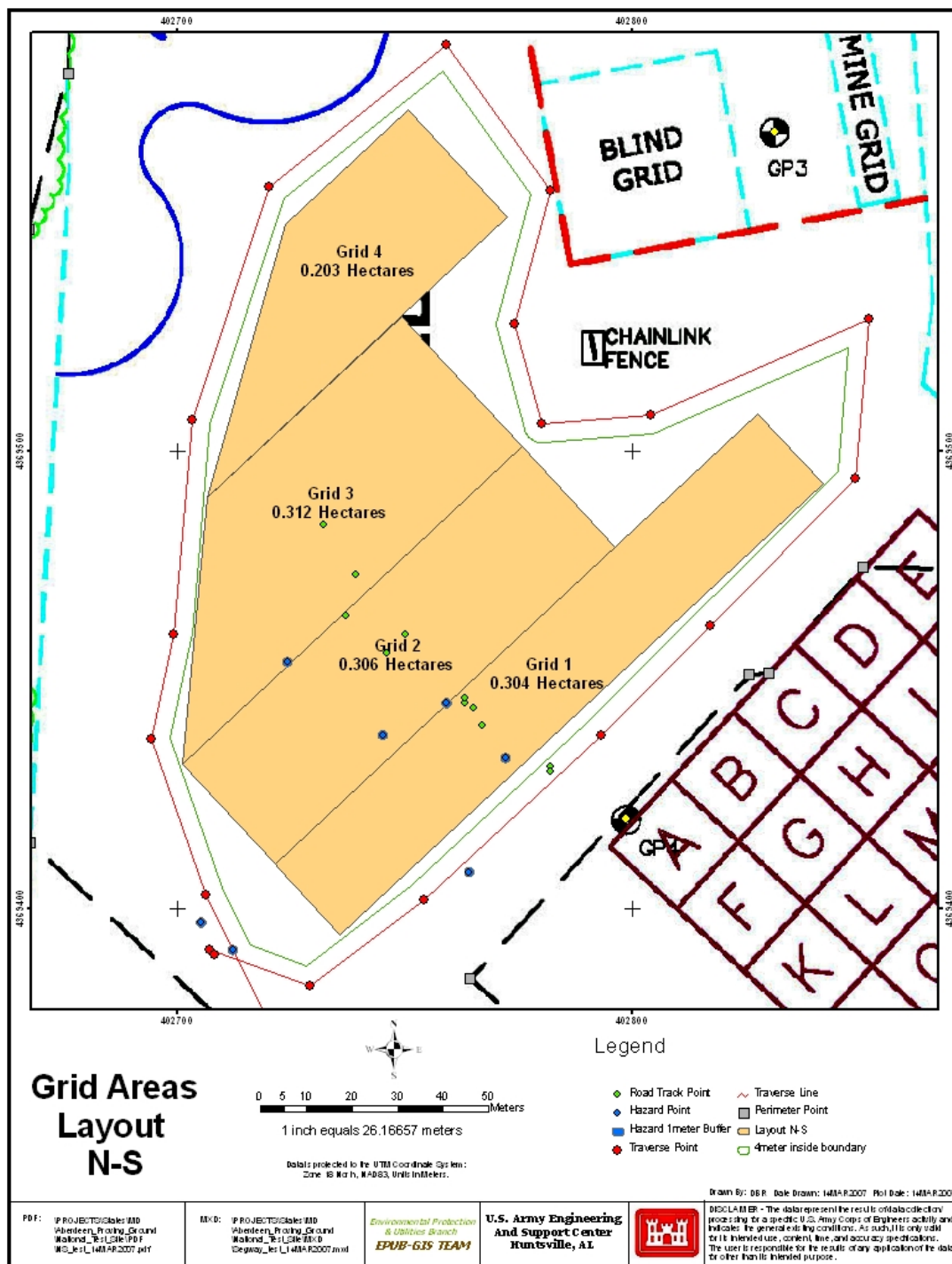
Composite of geophysical images for Grids 1-5. Gaps are caused by the water hazard obstacles

APG Open Field

RMP400, EM61-MK2

May2007

Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

Legend
+ targets
⬠ obstacles
— line path
☐ Grids 1-4
☐ Grid 5

APG Open Field
RMP400, EM61-MK2
May2007

Ch3 mV

25 0 25 50
(meters)
WGS 84 / UTM zone 18N

Open Field Dig List- Grid 1 by Robot 5/16/07

Remarks: This area was mapped before the site had several inches of rain. This survey uses positioning solely from the hitch angle sensor. The image from 5/21 used DGPS trailer positioning and navigates around the water hazards. Data is reported as Noisy, CH4- lots of spikes (pos & neg), full coverage (no obstacles), some gaps from bad line spacing, missing line on NW edge; one time jump (~32s, ~7.3m).

APG Open Field - Grid 1
RMP400 Robot-towed EM61MK2
With Hitch Angle Sensor - 5/16/07
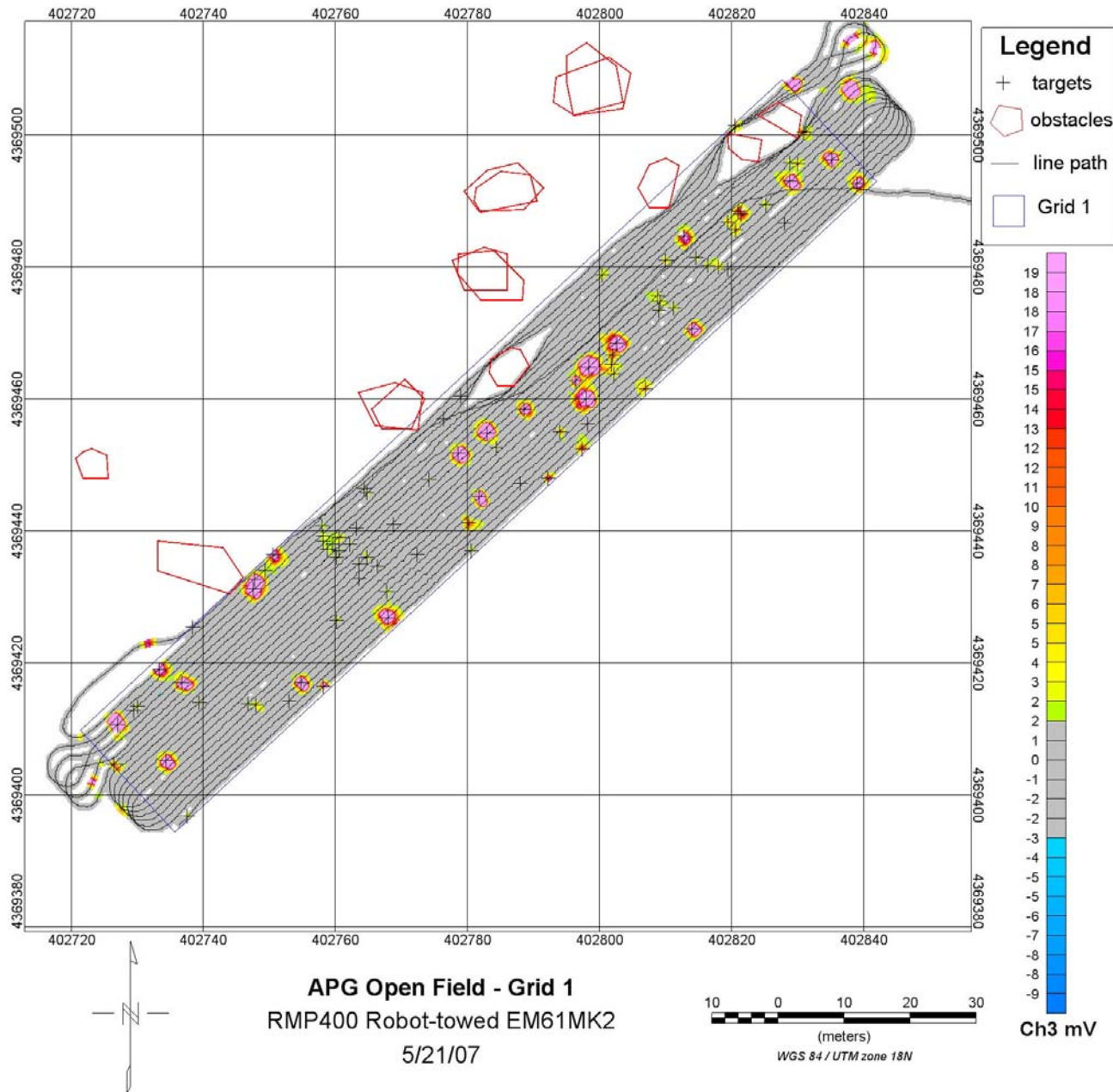
WGS 84 / UTM zone 18N

Ch3 mV
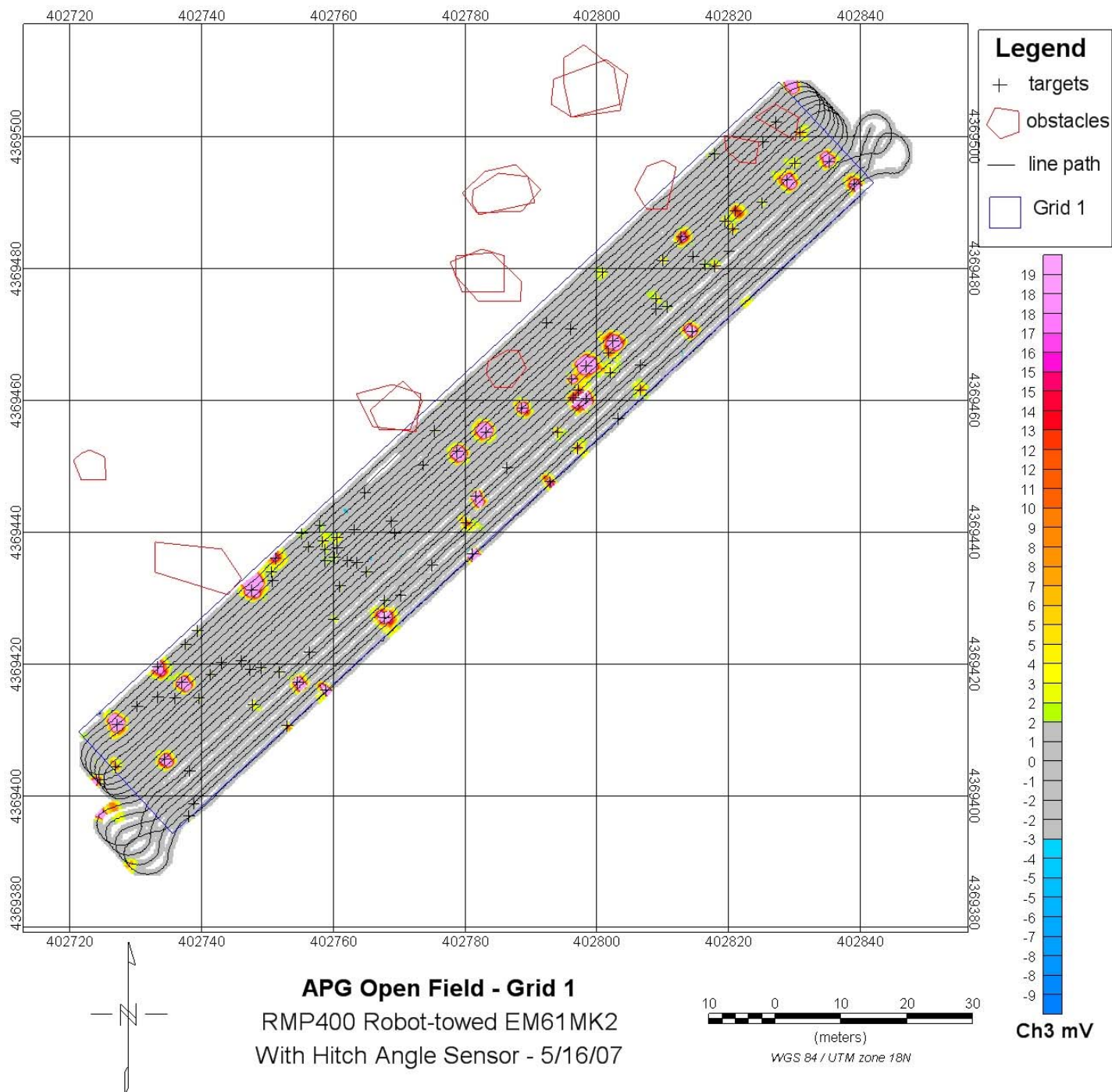
Transportable Manned and Robotic Digital Geophysical Mapping Tow Vehicle

Open Field Dig List- Grid 1 by Robot 5/16/07
(RMP_516_grid1)

Target_ID	x	y	ch3
1	402727.20	4369410.80	535.6
2	402747.60	4369431.20	226.2
3	402783.20	4369455.20	215.0
4	402798.40	4369465.20	207.7
5	402781.08	4369436.70	207.1
6	402778.80	4369452.20	141.5
7	402781.60	4369445.40	119.0
8	402798.31	4369460.28	102.5
9	402835.20	4369496.20	79.3
10	402802.40	4369469.00	74.4
11	402737.00	4369417.20	65.0
12	402788.60	4369458.80	56.2
13	402754.60	4369417.20	55.0
14	402767.80	4369427.00	54.8
15	402796.20	4369463.20	51.0
16	402828.80	4369493.40	47.9
17	402734.40	4369405.60	44.8
18	402814.40	4369470.40	42.8
19	402758.88	4369416.05	36.8
20	402839.00	4369492.80	34.7
21	402733.33	4369419.55	32.1
22	402812.80	4369484.80	18.2
23	402751.25	4369436.03	17.9
24	402792.82	4369447.64	17.6
25	402796.40	4369460.40	16.2
26	402797.16	4369461.55	15.6
27	402821.00	4369488.80	14.4
28	402801.80	4369467.20	11.7
29	402780.20	4369441.40	10.9
30	402797.00	4369452.80	10.5
31	402727.00	4369404.40	10.4
32	402752.96	4369410.62	9.8
33	402830.80	4369500.60	9.2
34	402820.60	4369486.00	8.6
35	402806.60	4369461.60	8.3
36	402794.00	4369455.20	7.6
37	402817.85	4369480.36	7.6
38	402810.00	4369481.20	6.8
39	402819.40	4369487.20	6.8
40	402802.00	4369464.20	5.9
41	402758.40	4369438.60	5.9
42	402830.00	4369496.00	5.9
43	402809.00	4369475.40	5.2
44	402739.40	4369425.02	5.0
45	402760.60	4369439.20	4.6
46	402747.80	4369413.80	4.5
47	402750.60	4369434.00	3.9
48	402760.20	4369436.20	3.7
49	402800.80	4369479.40	3.6
50	402741.40	4369418.40	3.6
51	402825.00	4369490.00	3.5
52	402758.80	4369437.40	3.3
53	402758.80	4369435.60	3.3
54	402816.40	4369480.60	3.3
55	402760.00	4369426.80	3.3
56	402739.60	4369414.80	3.2
57	402817.80	4369497.40	3.1
58	402769.40	4369439.80	2.8
59	402758.00	4369441.00	2.6
60	402749.00	4369419.40	2.4
61	402765.00	4369434.00	2.3
62	402751.80	4369418.80	2.3
63	402756.20	4369437.80	2.3
64	402806.60	4369465.40	2.3
65	402733.40	4369415.00	2.3
66	402768.80	4369441.60	2.2
67	402756.40	4369421.80	2.2
68	402775.40	4369455.40	2.1
69	402773.60	4369450.20	2.1
70	402737.60	4369423.00	2.1
71	402745.99	4369420.50	2.0
72	402827.20	4369502.20	2.0
73	402761.00	4369431.80	2.0
74	402755.23	4369439.79	2.0
75	402747.40	4369419.20	2.0
76	402730.20	4369413.60	1.9
77	402743.00	4369420.20	1.9
78	402738.08	4369396.93	1.9
79	402738.80	4369398.80	1.8
80	402764.80	4369446.00	1.8
81	402763.20	4369440.40	1.8
82	402796.00	4369470.80	1.8
83	402750.80	4369432.60	1.7
84	402763.60	4369435.40	1.7
85	402738.20	4369403.80	1.7
86	402825.20	4369499.20	1.7
87	402762.20	4369435.60	1.7
88	402814.60	4369481.80	1.7
89	402760.60	4369437.60	1.6
90	402810.60	4369474.20	1.6
91	402803.20	4369457.20	1.6
92	402770.20	4369430.40	1.6
93	402767.80	4369429.60	1.6
94	402820.00	4369482.60	1.6
95	402786.40	4369449.80	1.6
96	402792.40	4369471.80	1.6
97	402736.00	4369414.80	1.5
98	402809.00	4369473.80	1.5
99	402775.00	4369435.00	1.5

Open Field Dig List- Grid 1 by Robot 5/21/07 (RMP_521_grid1)
Remarks: Noisy, CH4- lots of spikes (pos & neg), mostly full coverage (2 obstacles), missing most of line on NW edge.

APG Open Field - Grid 1
RMP400 Robot-towed EM61MK2
5/21/07

Open Field Dig List- Grid 1 by Robot 5/21/07
(RMP_521_grid1)

Target_ID	x	y	ch3
1	402727.00	4369410.60	552.0
2	402798.40	4369464.80	203.6
3	402783.00	4369454.80	202.5
4	402747.60	4369431.20	194.6
5	402778.60	4369451.80	142.4
6	402781.80	4369445.20	123.9
7	402798.00	4369460.00	122.0
8	402747.80	4369432.60	106.4
9	402835.20	4369496.20	99.2
10	402802.60	4369468.40	77.2
11	402736.80	4369417.00	66.6
12	402754.80	4369417.00	62.3
13	402788.60	4369458.40	57.3
14	402796.40	4369462.80	55.4
15	402768.00	4369426.80	52.1
16	402828.80	4369493.00	51.0
17	402734.40	4369405.20	45.4
18	402814.00	4369470.60	43.6
19	402839.00	4369492.60	36.5
20	402758.20	4369416.40	31.3
21	402733.34	4369418.98	31.1
22	402750.60	4369436.40	21.7
23	402812.80	4369484.60	20.3
24	402792.20	4369448.00	19.3
25	402726.40	4369404.60	16.3
26	402802.00	4369466.60	13.8
27	402821.00	4369488.40	13.4
28	402797.40	4369452.40	13.4
29	402821.40	4369488.00	13.3
30	402780.20	4369441.20	10.1
31	402830.84	4369500.43	9.2
32	402794.00	4369455.00	9.0
33	402820.60	4369485.60	8.7
34	402819.40	4369486.80	8.3
35	402801.80	4369465.20	7.7
36	402820.50	4369501.41	7.7
37	402806.94	4369461.44	7.2
38	402802.20	4369463.80	6.8
39	402810.00	4369481.00	6.6
40	402748.00	4369413.60	6.1
41	402818.00	4369480.00	6.0
42	402760.60	4369439.00	6.0
43	402830.00	4369495.60	5.8
44	402809.20	4369474.80	5.5
45	402825.20	4369489.40	5.1
46	402808.80	4369475.60	4.9
47	402767.80	4369430.80	3.8
48	402816.40	4369480.20	3.8
49	402828.80	4369495.80	3.5
50	402758.00	4369440.80	3.3
51	402760.20	4369426.40	3.3
52	402800.40	4369478.80	3.3
53	402746.80	4369413.80	3.1
54	402758.20	4369438.40	3.0
55	402758.80	4369437.20	3.0
56	402764.80	4369436.00	2.9
57	402811.20	4369473.80	2.8
58	402784.40	4369452.60	2.8
59	402760.20	4369436.00	2.7
60	402759.60	4369438.00	2.7
61	402758.20	4369439.20	2.6
62	402780.60	4369437.00	2.6
63	402730.00	4369413.40	2.5
64	402764.80	4369445.80	2.5
65	402749.40	4369434.00	2.5
66	402739.40	4369414.00	2.4
67	402814.60	4369481.40	2.3
68	402779.00	4369460.40	2.3
69	402753.00	4369414.20	2.1
70	402766.40	4369434.60	2.1
71	402737.60	4369396.80	2.1
72	402809.00	4369473.40	2.0
73	402764.40	4369446.40	2.0
74	402763.60	4369435.00	1.9
75	402788.00	4369447.20	1.9
76	402828.00	4369486.60	1.8
77	402774.20	4369447.80	1.8
78	402772.40	4369436.40	1.8
79	402776.40	4369457.00	1.7
80	402819.40	4369479.60	1.7
81	402760.60	4369437.00	1.7
82	402768.80	4369441.00	1.7
83	402762.20	4369438.00	1.6
84	402729.40	4369412.80	1.6
85	402763.20	4369440.40	1.6
86	402798.20	4369456.20	1.6
87	402738.40	4369425.40	1.5
88	402763.60	4369432.80	1.5

Open Field Dig List- Grid 2 by Robot 5/20/07 (RMP_520_grid2)
Remarks: Some spikes (esp CH1), mostly full coverage except for obstacles, not quite to end of line at SW & NW corner.
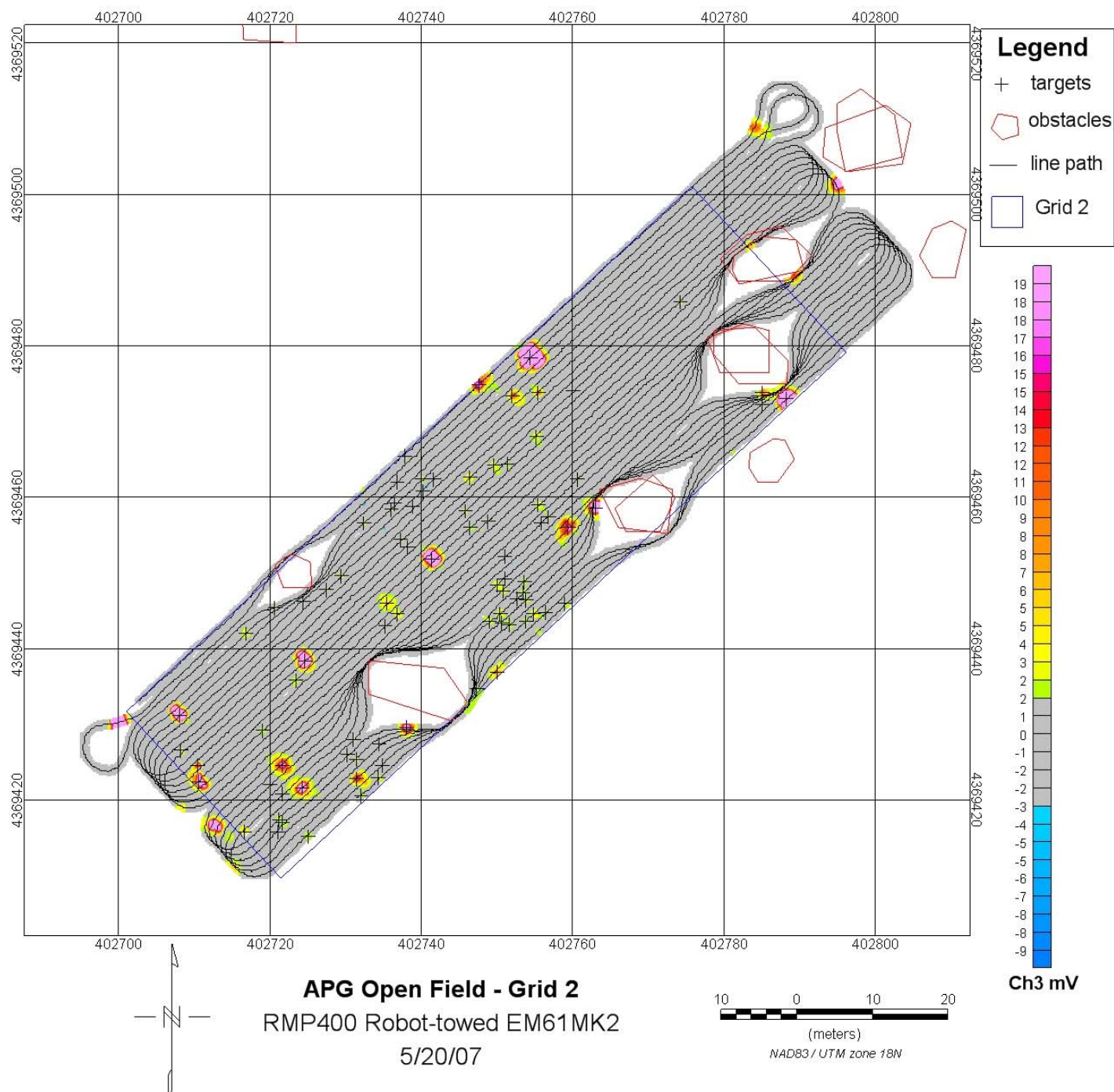
APG Open Field - Grid 2
RMP400 Robot-towed EM61MK2
5/20/07

NAD83 / UTM zone 18N

Ch3 mV

Open Field Dig List- Grid 2 by Robot 5/20/07
(RMP_520_grid2)

Target_ID	x	y	ch3
1	402754.40	4369478.40	1761.9
2	402788.19	4369473.00	303.7
3	402708.00	4369431.20	93.4
4	402724.60	4369438.40	75.8
5	402741.40	4369451.80	61.0
6	402763.00	4369458.60	54.4
7	402710.60	4369422.40	31.8
8	402724.20	4369421.60	30.2
9	402710.40	4369424.60	23.2
10	402738.00	4369429.60	20.7
11	402721.60	4369424.60	18.9
12	402747.60	4369474.80	18.5
13	402759.40	4369456.00	18.3
14	402731.40	4369422.80	17.4
15	402752.00	4369473.40	11.4
16	402785.00	4369473.80	9.9
17	402755.40	4369473.80	9.8
18	402716.60	4369415.80	6.9
19	402746.40	4369462.60	6.3
20	402749.97	4369436.92	6.0
21	402750.00	4369448.40	5.5
22	402736.80	4369444.60	5.1
23	402754.80	4369444.60	4.9
24	402750.40	4369444.60	4.9
25	402755.40	4369459.00	4.9
26	402735.40	4369446.00	4.7
27	402731.40	4369425.40	4.0
28	402749.60	4369464.20	3.8
29	402716.80	4369442.00	3.8
30	402750.80	4369447.60	3.8
31	402774.20	4369485.80	3.8
32	402729.40	4369449.60	3.4
33	402755.20	4369468.00	3.3
34	402708.20	4369426.60	3.2
35	402723.40	4369435.80	3.2
36	402734.25	4369423.00	3.1
37	402749.00	4369443.60	3.1
38	402753.40	4369447.40	2.9
39	402737.20	4369454.40	2.9
40	402745.80	4369458.20	2.8
41	402753.80	4369443.60	2.7
42	402758.97	4369445.97	2.7
43	402720.60	4369445.40	2.6
44	402734.40	4369427.40	2.6
45	402751.60	4369443.20	2.5
46	402753.80	4369446.40	2.5
47	402719.00	4369429.20	2.5
48	402721.20	4369417.40	2.5
49	402725.00	4369415.20	2.4
50	402747.34	4369434.74	2.4
51	402721.60	4369417.00	2.4
52	402746.40	4369456.00	2.4
53	402736.00	4369458.40	2.4
54	402740.00	4369462.40	2.4
55	402741.60	4369462.40	2.3
56	402751.40	4369464.40	2.3
57	402727.40	4369447.80	2.2
58	402724.40	4369446.20	2.2
59	402750.60	4369443.40	2.2
60	402731.00	4369428.00	2.1
61	402753.60	4369448.80	2.1
62	402738.20	4369453.40	1.9
63	402785.00	4369472.20	1.9
64	402736.80	4369462.00	1.9
65	402748.80	4369456.80	1.9
66	402720.00	4369422.00	1.8
67	402732.40	4369456.60	1.8
68	402740.20	4369460.80	1.8
69	402755.80	4369456.60	1.8
70	402738.80	4369458.80	1.8
71	402735.20	4369443.00	1.7
72	402736.40	4369459.20	1.7
73	402730.20	4369426.00	1.7
74	402752.60	4369446.60	1.7
75	402721.60	4369420.80	1.7
76	402751.00	4369452.20	1.7
77	402732.00	4369420.60	1.6
78	402756.80	4369457.40	1.6
79	402760.60	4369462.40	1.6
80	402721.00	4369415.80	1.6
81	402737.80	4369465.40	1.6
82	402751.00	4369449.20	1.6
83	402760.00	4369474.00	1.5
84	402756.40	4369444.80	1.5
85	402734.80	4369424.60	1.5

Open Field Dig List- Grid 3 by Robot 5/16/07 (RMP_516_grid3)
Remarks: Mostly full coverage, no obstacles, 1 gap down middle from bad line spacing, starts ~7m in from NW edge, time jump (~36s, ~4.8m - outside grid); ~10m gap, ~2.5min stop (starts back on next line)

APG Open Field - Grid 3
RMP400 Robot-towed EM61MK2
w/ Hitch Angle Sensor, 5/16/07

Open Field Dig List- Grid 3 by Robot 5/16/07
(RMP_516_grid3)

Target_ID	x	y	ch3
1	402764.40	4369495.20	382.8
2	402748.60	4369481.80	313.1
3	402710.40	4369480.40	301.5
4	402760.58	4369491.92	229.7
5	402735.20	4369501.80	125.3
6	402716.20	4369449.00	69.5
7	402708.80	4369443.40	61.8
8	402729.60	4369484.20	55.8
9	402746.80	4369518.67	50.7
10	402709.20	4369461.00	35.2
11	402747.52	4369475.37	18.6
12	402716.80	4369465.40	16.8
13	402746.60	4369493.20	16.1
14	402732.25	4369512.50	15.1
15	402734.60	4369498.60	13.8
16	402731.00	4369507.20	9.4
17	402758.20	4369509.40	7.5
18	402704.60	4369449.40	4.3
19	402708.40	4369465.00	4.2
20	402724.60	4369461.80	3.4
21	402748.80	4369521.20	3.3
22	402734.80	4369467.60	2.8
23	402727.40	4369464.20	2.8
24	402715.60	4369447.20	2.6
25	402733.60	4369466.40	2.4
26	402728.60	4369466.80	2.3
27	402724.20	4369486.20	2.2
28	402716.00	4369460.40	2.1
29	402715.60	4369480.80	2.1
30	402725.80	4369476.20	2.1
31	402726.60	4369475.80	2.1
32	402716.40	4369480.60	2.1
33	402730.80	4369463.80	2.0
34	402741.60	4369489.40	2.0
35	402722.80	4369482.20	2.0
36	402718.20	4369482.20	1.9
37	402723.80	4369481.60	1.8
38	402734.20	4369462.80	1.8
39	402716.20	4369454.20	1.8
40	402714.20	4369478.40	1.8
41	402729.80	4369464.20	1.7
42	402736.80	4369466.40	1.6
43	402720.00	4369485.20	1.6
44	402726.00	4369459.40	1.6
45	402747.60	4369487.00	1.6
46	402713.80	4369448.00	1.6
47	402733.00	4369464.40	1.6
48	402720.60	4369462.20	1.6
49	402719.20	4369499.20	1.6
50	402730.80	4369472.60	1.5
51	402717.80	4369468.80	1.5

Open Field Dig List- Grid 4 by Robot 5/16/07 (RMP_516_grid4)
Remarks: Missing southern part of grid (~9 lines); some time jumps; one obstacle; some spikes
on CH1 & 4, 5.75 min of static at end of data (didn't finish grid- GPS battery failure)
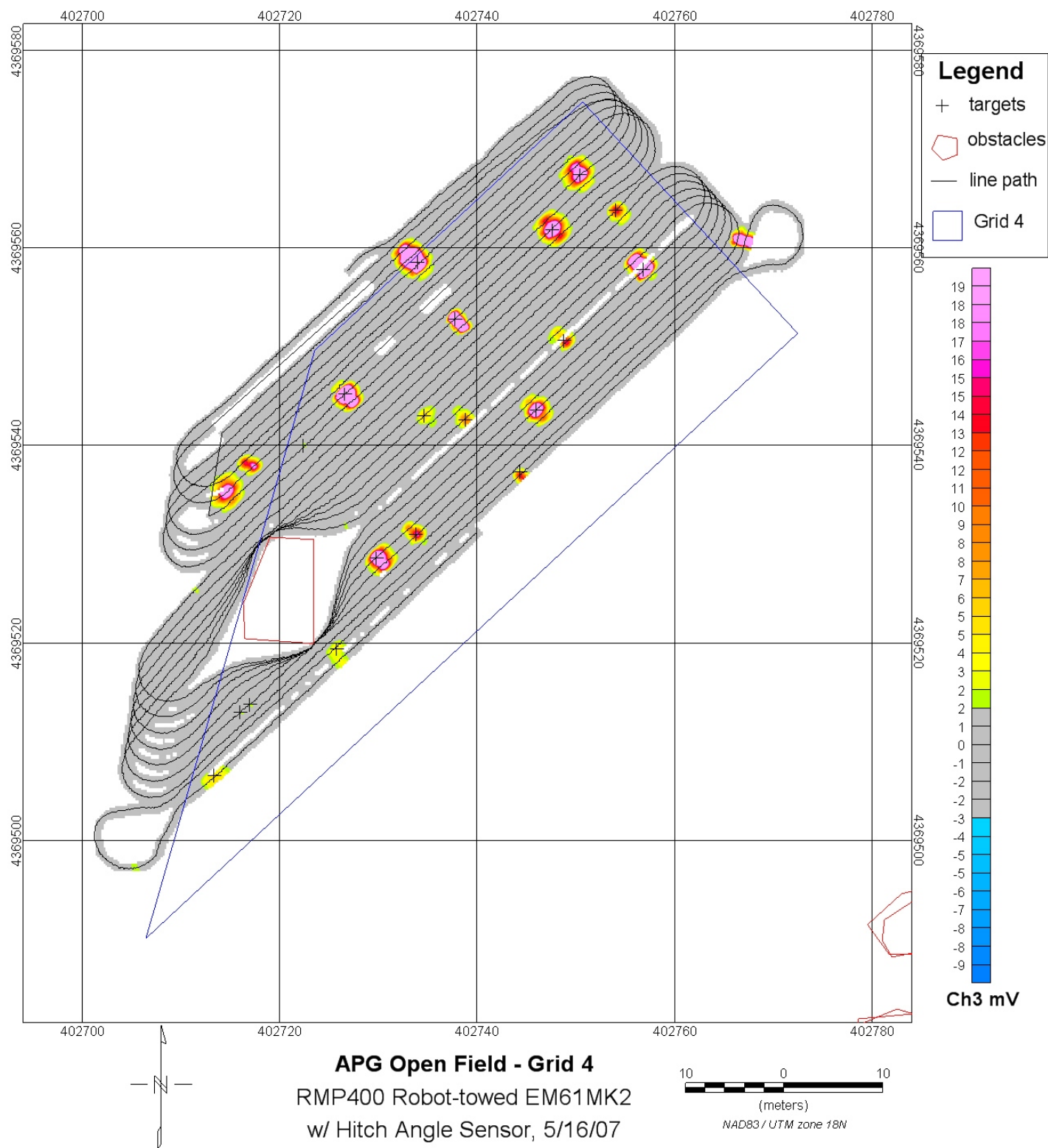
APG Open Field - Grid 4
RMP400 Robot-towed EM61MK2
w/ Hitch Angle Sensor, 5/16/07

NAD83 / UTM zone 18N

Open Field Dig List- Grid 4 by Robot 5/16/07
(RMP_516_grid4)
(missing southern section of grid)

Target_ID	X	Y	ch3
1	402726.60	4369545.20	157.41
2	402756.80	4369557.80	103.82
3	402737.80	4369552.80	95.16
4	402733.96	4369558.55	61.43
5	402746.00	4369543.60	38.54
6	402729.80	4369528.60	37.62
7	402747.60	4369561.80	37.42
8	402750.40	4369567.40	30.15
9	402733.80	4369531.00	16.41
10	402748.80	4369550.60	15.53
11	402754.00	4369563.80	14.46
12	402738.80	4369542.60	8.90
13	402744.36	4369537.35	7.11
14	402734.60	4369543.00	5.10
15	402713.36	4369506.61	4.70
16	402725.80	4369519.40	3.58
17	402717.00	4369513.80	2.34
18	402722.40	4369540.00	2.15
19	402716.00	4369513.00	1.64

Open Field Dig List- Grid 4 by Robot 5/17/07 (RMP_517_grid4)
Remarks: Ch4 lots of spikes, mostly full coverage, one obstacle, one time jump (~36s, ~28m), some gaps from lane spacing
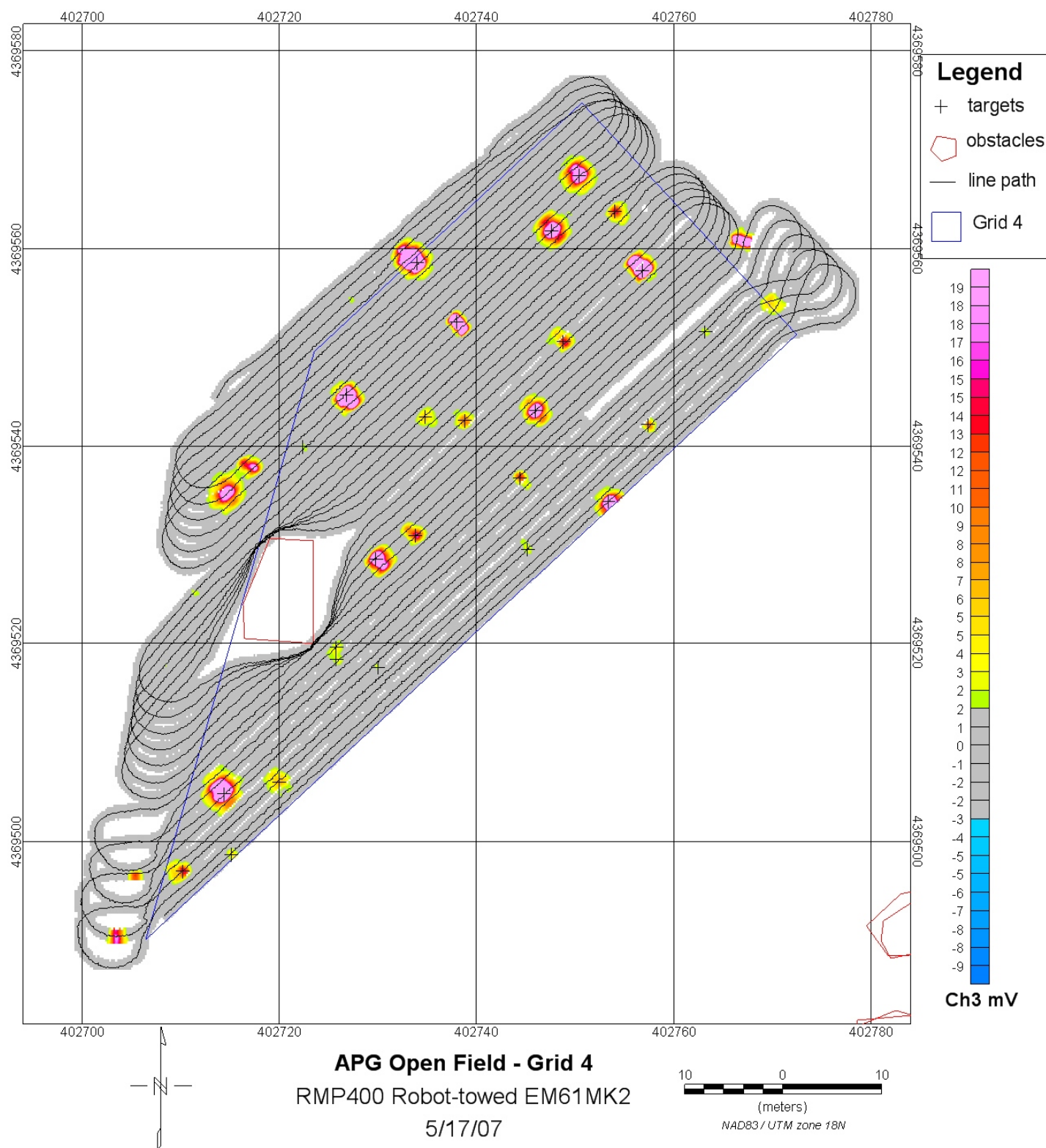

APG Open Field - Grid 4
RMP400 Robot-towed EM61MK2
5/17/07

Open Field Dig List- Grid 4 by Robot 5/17/07
(RMP_517_grid4)

Target_ID	X	Y	ch3
1	402726.80	4369545.20	151.8
2	402738.00	4369552.60	108.1
3	402756.80	4369557.80	103.1
4	402733.96	4369558.55	57.3
5	402714.40	4369504.80	45.7
6	402746.00	4369543.60	39.2
7	402729.80	4369528.60	38.1
8	402747.60	4369561.80	37.6
9	402753.38	4369534.44	35.4
10	402750.40	4369567.40	30.1
11	402733.80	4369531.00	16.0
12	402748.80	4369550.60	15.3
13	402710.20	4369497.00	14.7
14	402754.00	4369563.80	14.6
15	402744.40	4369536.80	13.9
16	402757.40	4369542.20	9.5
17	402738.80	4369542.60	9.1
18	402720.00	4369506.00	6.6
19	402734.80	4369543.00	5.7
20	402715.13	4369498.68	4.1
21	402725.80	4369519.60	3.6
22	402745.20	4369529.60	3.1
23	402763.20	4369551.60	3.0
24	402725.80	4369518.40	2.8
25	402722.40	4369540.00	2.6
26	402730.00	4369517.60	2.5

Open Field Dig List- Grid 4 by Robot 5/18/07 (RMP_518_grid4)
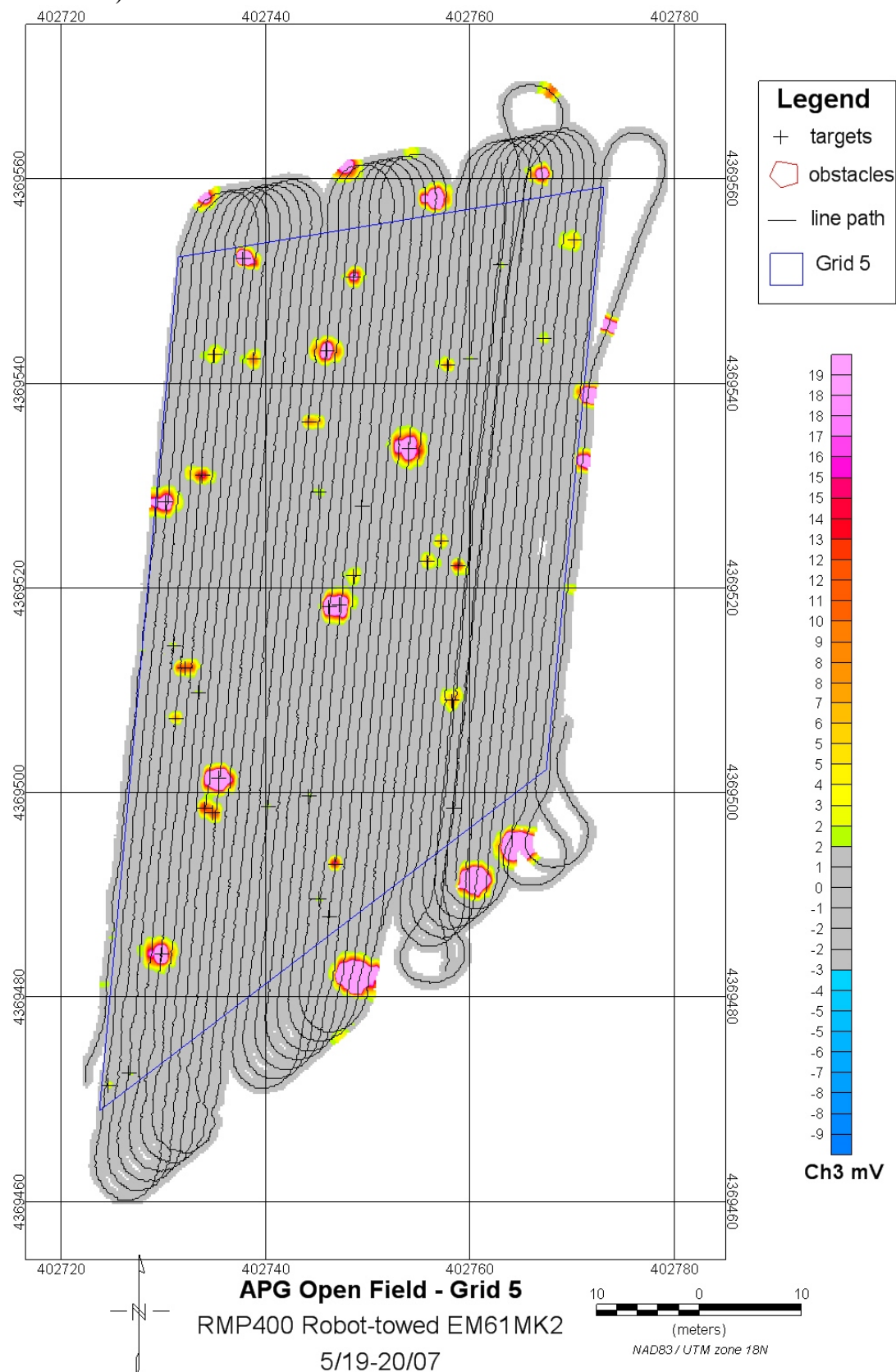Remarks: Ch4 lots of spikes, full coverage except one obstacle
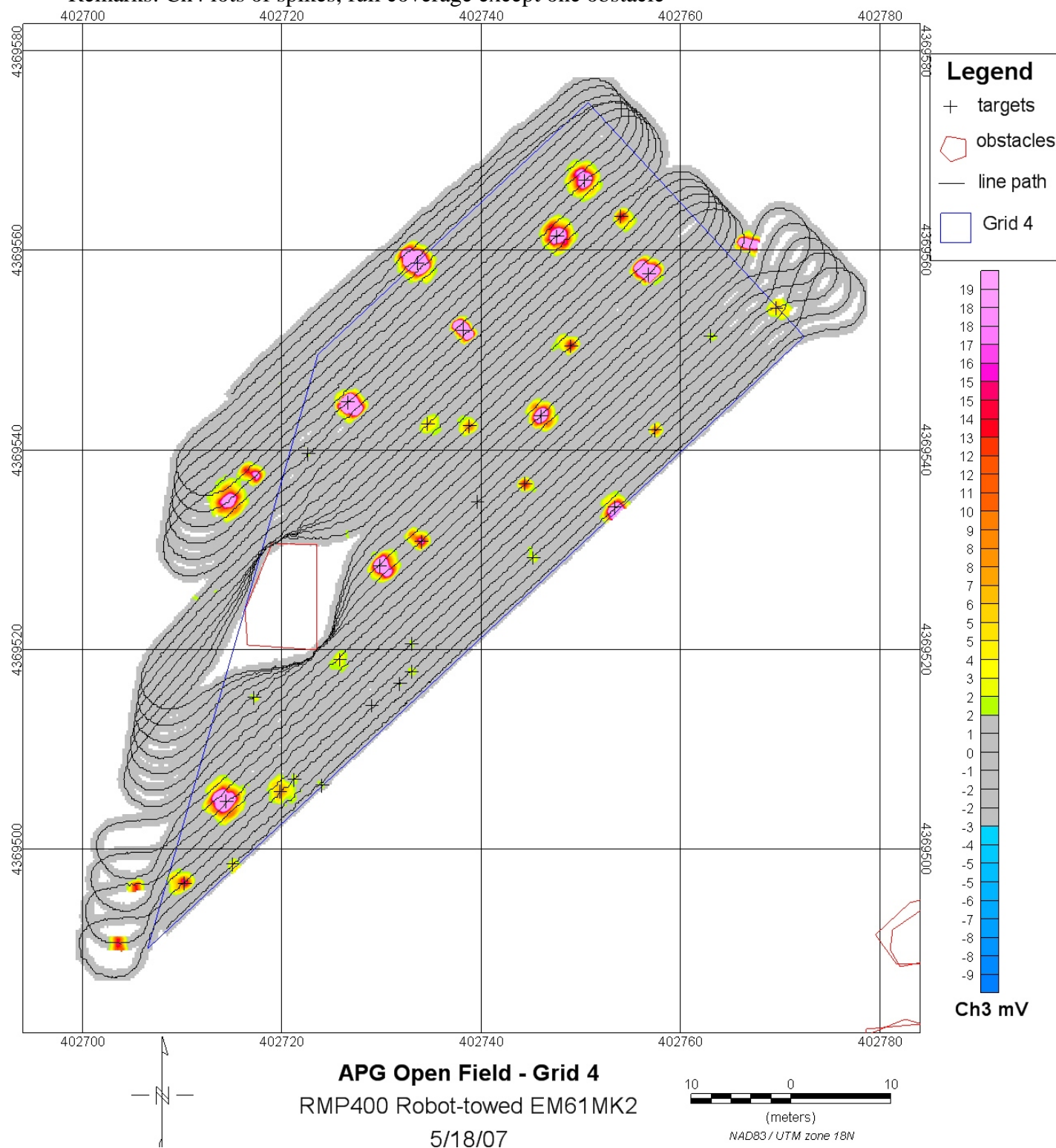
APG Open Field - Grid 4
RMP400 Robot-towed EM61MK2
5/18/07

(meters)

NAD83 / UTM zone 18N

Open Field Dig List- Grid 4 by Robot 5/18/07
(RMP_518_grid4)

Target_ID	x	y	ch3
1	402726.60	4369544.80	154.6
2	402733.57	4369558.71	102.0
3	402756.80	4369557.60	101.7
4	402738.20	4369552.00	92.6
5	402714.40	4369504.80	44.4
6	402746.00	4369543.40	39.8
7	402729.80	4369528.40	38.8
8	402747.60	4369561.40	37.5
9	402753.38	4369534.28	33.3
10	402750.40	4369567.00	31.0
11	402734.00	4369530.80	17.3
12	402710.20	4369496.60	15.6
13	402749.00	4369550.40	14.4
14	402754.00	4369563.40	14.3
15	402744.40	4369536.60	13.4
16	402757.40	4369542.00	9.6
17	402738.80	4369542.40	8.8
18	402719.80	4369505.80	6.8
19	402769.60	4369554.20	5.9
20	402734.60	4369542.60	5.4
21	402715.03	4369498.52	4.5
22	402725.80	4369519.00	3.4
23	402745.20	4369529.20	3.3
24	402721.20	4369507.00	3.0
25	402763.00	4369551.40	2.8
26	402733.00	4369517.80	2.7
27	402717.20	4369515.20	2.5
28	402733.00	4369520.60	2.1
29	402724.00	4369506.40	1.9
30	402731.80	4369516.60	1.7
31	402739.60	4369534.80	1.6
32	402722.60	4369539.60	1.6
33	402729.00	4369514.40	1.5

Open Field Dig List- Grid 5 by Robot 5/19-20/07 (RMP_519_520_grid5)
Remarks: Full coverage, good line spacing, good line spacing, 4 time/distance gaps (largest ~11m/~14s)

APG Open Field - Grid 5
RMP400 Robot-towed EM61MK2
5/19-20/07

—N—

(meters)

NAD83 / UTM zone 18N

Open Field Dig List- Grid 5 by Robot 5/19-
20/07 (RMP_519_520_grid5)

Target_ID	x	y	ch3
1	402737.80	4369552.20	181.6
2	402735.40	4369501.40	153.6
3	402746.20	4369518.20	56.3
4	402754.00	4369533.60	49.4
5	402729.80	4369484.20	48.3
6	402747.20	4369518.40	46.4
7	402746.00	4369543.20	33.9
8	402730.20	4369528.40	33.0
9	402748.60	4369550.40	22.0
10	402746.80	4369493.00	16.8
11	402733.80	4369531.00	16.6
12	402758.80	4369522.20	15.9
13	402734.00	4369498.40	14.8
14	402732.12	4369512.22	12.0
15	402734.80	4369498.00	11.6
16	402738.80	4369542.40	9.1
17	402744.20	4369536.20	9.1
18	402757.80	4369541.80	8.7
19	402758.20	4369509.00	7.6
20	402731.20	4369507.20	7.4
21	402757.20	4369524.60	6.3
22	402755.80	4369522.60	5.9
23	402770.20	4369554.00	5.3
24	402735.00	4369542.80	4.7
25	402748.60	4369521.20	4.4
26	402724.60	4369471.40	4.4
27	402731.00	4369514.40	3.6
28	402767.20	4369544.40	3.5
29	402760.00	4369542.40	3.2
30	402763.00	4369551.60	3.1
31	402733.40	4369509.80	2.6
32	402740.20	4369498.60	2.3
33	402745.20	4369489.60	2.3
34	402745.20	4369529.40	2.2
35	402744.20	4369499.60	2.0
36	402758.40	4369498.40	1.8
37	402726.60	4369472.60	1.7
38	402749.40	4369528.00	1.6
39	402746.20	4369487.80	1.5

Open Field Dig List- Grid 4 by Man towed 5/18/07 (MP_518_grid4)
Remarks: Top Ch & Ch3 very noisy, full coverage except gaps from lane spacing, data only at
9Hz b/c of data collector speed limitation (gives some zero velocity)
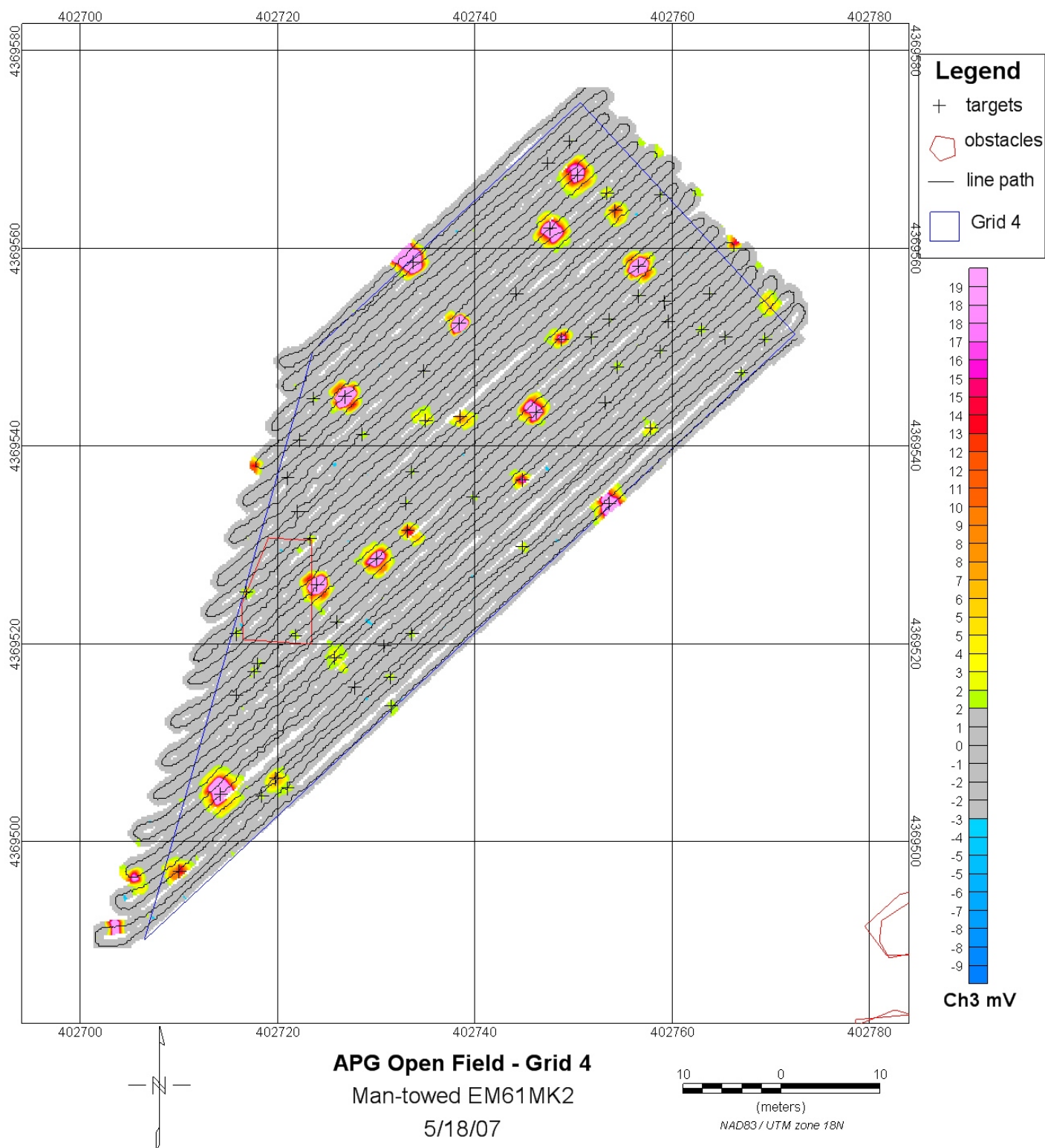
APG Open Field - Grid 4

Man-towed EM61MK2

5/18/07

NAD83 / UTM zone 18N

Open Field Dig List- Grid 4 by Man towed
5/18/07 (MP_518_grid4)

Target_ID	x	y	ch3
1	402738.40	4369552.40	260.4
2	402724.00	4369526.00	177.5
3	402726.80	4369545.00	176.9
4	402756.60	4369558.20	140.5
5	402733.75	4369558.61	84.0
6	402714.20	4369504.80	45.2
7	402753.58	4369534.21	44.1
8	402747.60	4369562.00	39.6
9	402730.00	4369528.60	39.0
10	402746.20	4369543.40	35.3
11	402750.40	4369567.40	32.9
12	402748.80	4369550.80	21.2
13	402744.80	4369536.60	19.4
14	402733.16	4369531.44	14.2
15	402710.00	4369497.00	13.7
16	402754.20	4369563.80	12.6
17	402738.49	4369542.99	8.6
18	402719.80	4369506.40	6.6
19	402735.00	4369542.60	4.4
20	402757.82	4369541.85	4.2
21	402753.40	4369565.60	3.9
22	402725.80	4369518.60	3.7
23	402716.80	4369525.20	3.3
24	402731.40	4369516.60	3.2
25	402723.30	4369530.63	3.0
26	402744.80	4369529.81	2.9
27	402715.80	4369521.00	2.8
28	402717.60	4369517.20	2.7
29	402721.00	4369505.40	2.7
30	402754.40	4369548.00	2.5
31	402753.60	4369552.80	2.4
32	402721.80	4369520.80	2.4
33	402763.00	4369551.80	2.3
34	402718.40	4369504.60	2.2
35	402733.60	4369537.40	2.2
36	402739.80	4369534.80	2.2
37	402728.60	4369541.20	2.2
38	402718.00	4369518.00	2.1
39	402733.60	4369521.00	2.1
40	402723.60	4369544.80	2.1
41	402767.00	4369547.40	2.0
42	402769.40	4369550.80	2.0
43	402731.48	4369513.71	1.8
44	402765.40	4369551.00	1.8
45	402758.80	4369565.40	1.7
46	402758.80	4369549.60	1.7
47	402734.80	4369547.60	1.7
48	402751.80	4369551.00	1.7
49	402726.00	4369522.20	1.7
50	402756.60	4369555.20	1.7
51	402747.40	4369568.60	1.7
52	402759.60	4369552.60	1.6
53	402727.80	4369515.60	1.6
54	402759.20	4369554.60	1.6
55	402744.20	4369555.40	1.6
56	402722.20	4369540.60	1.6
57	402753.20	4369544.40	1.6
58	402730.80	4369519.80	1.6
59	402715.80	4369514.80	1.6
60	402733.00	4369534.20	1.6
61	402763.80	4369555.40	1.6
62	402722.00	4369533.40	1.5
63	402721.00	4369536.80	1.5
64	402749.60	4369570.80	1.5

Open Field Dig List- Grid 4 by XT 5/18/07 (XT_518_grid4_try2)
Remarks: 4 lines- extra line is fix quality '1' that was not in xyz file- shouldn't trust positioning though. Time jump from xyz was also quality '1' and shows up offset from line path.
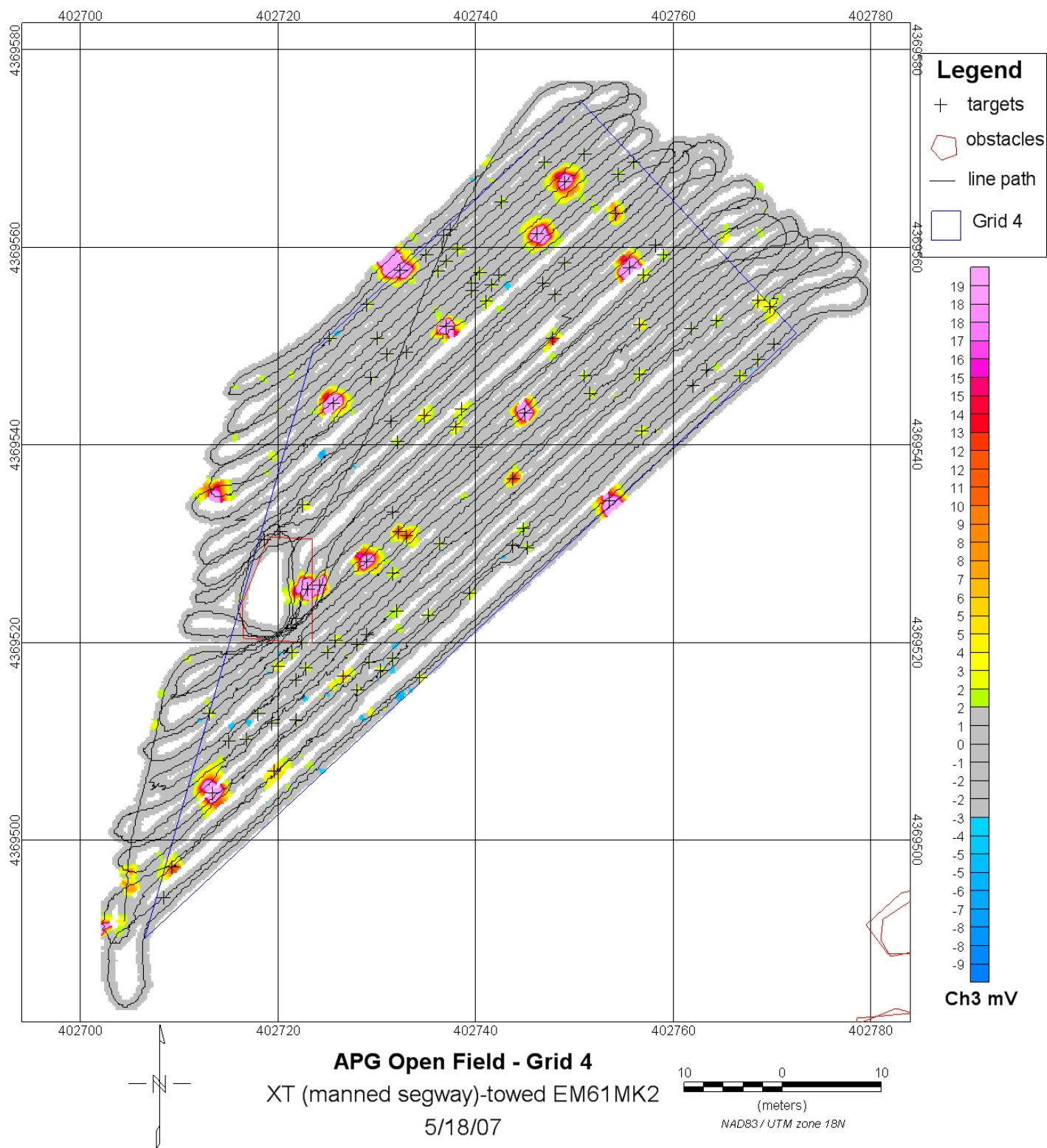
APG Open Field - Grid 4
XT (manned segway)-towed EM61MK2
5/18/07

Open Field Dig List- Grid 4 by XT 5/18/07
(XT_518_grid4_try2)
 note: bad GPS, r61 import

Target_ID	X	Y	ch3
1	402724.20	4369525.80	181.2
2	402737.00	4369552.00	171.5
3	402723.00	4369525.40	164.6
4	402725.60	4369544.20	148.6
5	402755.55	4369557.96	127.0
6	402732.37	4369557.64	56.5
7	402746.20	4369561.40	39.3
8	402745.00	4369543.20	36.0
9	402713.33	4369504.76	34.3
10	402729.00	4369528.20	33.4
11	402749.00	4369566.60	31.2
12	402753.50	4369534.32	30.1
13	402743.80	4369536.60	13.3
14	402747.76	4369550.80	13.3
15	402733.00	4369530.80	12.3
16	402709.29	4369497.27	11.5
17	402732.20	4369531.20	10.9
18	402754.20	4369563.40	9.1
19	402756.60	4369552.20	6.5
20	402726.60	4369516.60	6.5
21	402719.60	4369507.00	6.4
22	402720.00	4369517.60	5.4
23	402728.00	4369515.20	5.3
24	402738.00	4369541.80	5.1
25	402734.80	4369543.00	4.8
26	402768.60	4369554.60	4.8
27	402722.80	4369517.40	4.8
28	402769.80	4369554.00	4.5
29	402725.80	4369520.20	4.1
30	402756.80	4369541.40	3.9
31	402738.20	4369559.80	3.7
32	402730.40	4369517.20	3.7
33	402713.00	4369512.80	3.7
34	402734.34	4369516.47	3.4
35	402756.60	4369547.20	3.3
36	402721.40	4369519.00	3.1
37	402722.52	4369533.90	3.0
38	402757.00	4369557.20	3.0
39	402766.80	4369547.00	3.0
40	402751.60	4369545.20	2.8
41	402736.40	4369530.00	2.8
42	402738.56	4369543.65	2.8
43	402725.20	4369550.80	2.7
44	402741.60	4369556.20	2.6
45	402731.60	4369527.00	2.6
46	402741.05	4369554.55	2.6
47	402739.40	4369524.99	2.6
48	402731.97	4369523.18	2.5
49	402729.00	4369554.20	2.5
50	402735.20	4369522.80	2.4
51	402751.00	4369547.00	2.3
52	402764.38	4369552.56	2.3
53	402740.40	4369557.40	2.2
54	402749.00	4369558.40	2.2
55	402729.20	4369518.00	2.2
56	402722.40	4369520.00	2.2
57	402763.40	4369547.60	2.2
58	402721.80	4369522.40	2.1
59	402731.60	4369518.40	2.1
60	402736.20	4369557.60	2.1
61	402768.60	4369548.60	2.1
62	402759.00	4369559.20	2.1
63	402745.20	4369529.60	2.0
64	402754.40	4369567.40	2.0
65	402744.80	4369531.54	2.0
66	402725.00	4369519.00	2.0
67	402756.00	4369568.60	2.0
68	402730.00	4369550.80	2.0
69	402735.00	4369559.20	1.9
70	402732.06	4369540.31	1.9
71	402737.00	4369558.60	1.9
72	402728.00	4369519.80	1.8
73	402719.40	4369511.80	1.8
74	402716.80	4369510.20	1.8
75	402761.80	4369551.80	1.8
76	402746.80	4369556.40	1.8
77	402740.00	4369539.80	1.8
78	402737.40	4369561.80	1.8
79	402742.60	4369564.60	1.8
80	402758.20	4369560.20	1.7
81	402743.80	4369529.80	1.7
82	402751.00	4369569.40	1.7
83	402733.00	4369549.40	1.7
84	402731.60	4369533.20	1.7
85	402729.40	4369546.80	1.7
86	402736.60	4369560.00	1.7
87	402718.60	4369530.40	1.7
88	402720.20	4369531.20	1.6
89	402731.00	4369549.20	1.6
90	402721.80	4369516.20	1.6
91	402747.00	4369568.60	1.6
92	402739.60	4369556.40	1.6
93	402729.00	4369520.80	1.6
94	402708.40	4369494.20	1.6
95	402731.40	4369542.40	1.6
96	402748.00	4369555.20	1.6
97	402718.00	4369512.80	1.6
98	402715.00	4369510.00	1.6
99	402762.00	4369546.00	1.6
100	402739.60	4369555.60	1.6

101	402742.40	4369557.20	1.6
102	402770.20	4369550.20	1.6
103	402721.80	4369512.20	1.5
104	402736.80	4369561.20	1.5

Open Field Dig List- Grid 4 by XT 5/21/07 (XT_521_grid4)
Remarks: Bad GPS quality (mostly 1's and 5's- only ~2.5 lines with RTK fix/quality 4). Deleted & interpolated when jump from obvious path- 4 places. Positioning off even when looks like on path- One large anomaly showing up inside eastern edge of 'background' polygon - was outside the ply bounds for all other data sets, doesn't look like a latency issue. Basically- can't trust the positioning on this dataset, would fail and be recollected. Top Ch very noisy- overall more background noise.
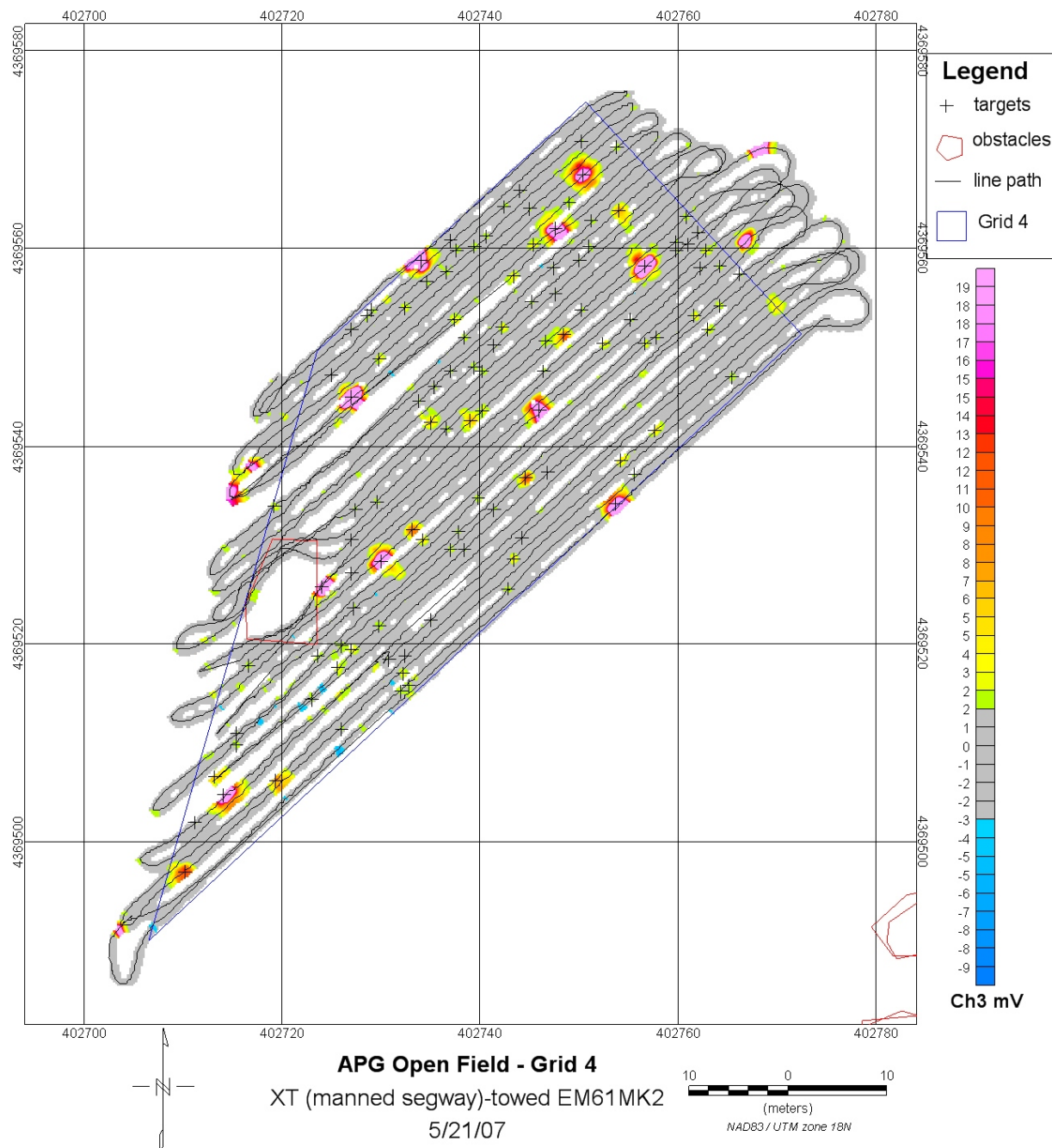
APG Open Field - Grid 4
XT (manned segway)-towed EM61MK2
5/21/07

NAD83 / UTM zone 18N

Open Field Dig List- Grid 4 by XT 5/21/07
(XT_521_grid4)

note: noisier data, probably should use a higher threshold, lots of small targets that aren't in other grids.

Target_ID	X	Y	ch3
1	402724.00	4369525.80	166.7
2	402727.00	4369545.00	166.2
3	402756.60	4369558.20	113.7
4	402734.05	4369558.78	58.1
5	402753.68	4369534.21	45.0
6	402714.12	4369504.76	39.8
7	402730.00	4369528.40	38.0
8	402747.60	4369562.00	35.6
9	402745.98	4369543.64	34.1
10	402750.40	4369567.40	29.1
11	402710.20	4369497.00	12.7
12	402744.60	4369536.80	12.0
13	402748.45	4369551.29	10.6
14	402733.16	4369531.60	9.3
15	402719.35	4369506.22	7.6
16	402754.00	4369563.80	6.8
17	402739.00	4369542.60	6.3
18	402713.20	4369506.60	5.5
19	402743.40	4369528.60	5.0
20	402735.00	4369542.40	4.7
21	402757.60	4369541.60	4.6
22	402734.20	4369530.60	3.9
23	402727.00	4369519.40	3.7
24	402732.40	4369554.00	3.7
25	402729.80	4369548.80	3.7
26	402754.20	4369538.60	3.6
27	402745.40	4369560.40	3.6
28	402742.20	4369552.00	3.5
29	402743.40	4369557.20	3.5
30	402764.20	4369554.20	3.3
31	402761.60	4369553.20	3.2
32	402725.60	4369517.60	3.2
33	402763.00	4369551.80	3.2
34	402762.80	4369559.80	3.2
35	402752.40	4369550.40	3.0
36	402756.60	4369550.40	3.0
37	402732.80	4369515.80	2.8
38	402726.00	4369519.80	2.8
39	402739.80	4369534.80	2.8
40	402732.20	4369517.00	2.8
41	402737.40	4369552.80	2.8
42	402738.40	4369551.00	2.8
43	402742.80	4369525.60	2.7
44	402719.20	4369534.00	2.7
45	402757.80	4369551.00	2.7
46	402732.00	4369515.20	2.7
47	402715.40	4369509.80	2.6
48	402737.00	4369529.60	2.6
49	402740.20	4369543.60	2.6
50	402759.80	4369560.60	2.5
51	402762.20	4369558.00	2.5
52	402764.20	4369558.20	2.4
53	402765.40	4369547.00	2.4
54	402751.20	4369562.80	2.4
55	402746.60	4369550.60	2.4
56	402750.20	4369570.80	2.3
57	402716.60	4369517.80	2.3
58	402729.80	4369521.80	2.3
59	402749.00	4369564.60	2.2
60	402737.80	4369531.40	2.2
61	402737.60	4369559.80	2.1
62	402753.80	4369570.20	2.1
63	402736.60	4369557.60	2.1
64	402760.80	4369563.20	2.1
65	402745.20	4369554.60	2.1
66	402739.40	4369548.00	2.1
67	402740.20	4369547.60	2.1
68	402729.60	4369534.40	2.1
69	402766.20	4369557.40	2.0
70	402715.40	4369511.00	2.0
71	402734.60	4369556.60	2.0
72	402740.60	4369561.20	1.9
73	402727.40	4369533.60	1.9
74	402736.60	4369541.80	1.9
75	402751.00	4369560.20	1.9
76	402739.40	4369560.20	1.9
77	402729.00	4369553.80	1.8
78	402723.60	4369518.80	1.8
79	402723.00	4369514.40	1.8
80	402738.40	4369529.60	1.8
81	402741.40	4369533.60	1.8
82	402747.40	4369558.00	1.7
83	402742.40	4369564.20	1.7
84	402727.20	4369523.60	1.7
85	402759.80	4369559.80	1.7
86	402745.00	4369564.00	1.7
87	402737.00	4369560.80	1.7
88	402737.00	4369547.60	1.7
89	402726.00	4369511.40	1.7
90	402746.40	4369547.60	1.7
91	402732.40	4369518.80	1.7
92	402735.40	4369546.00	1.7
93	402750.00	4369558.80	1.7

94	402733.80	4369544.60	1.7
95	402755.20	4369552.80	1.6
96	402762.00	4369561.60	1.6
97	402746.80	4369537.40	1.6
98	402755.60	4369537.20	1.6
99	402750.20	4369553.80	1.6
100	402727.00	4369527.20	1.6
101	402728.60	4369553.20	1.6
102	402711.20	4369502.00	1.6
103	402761.00	4369560.40	1.6
104	402730.80	4369518.40	1.6
105	402725.00	4369547.20	1.6
106	402727.00	4369551.80	1.6
107	402744.20	4369530.80	1.6
108	402741.40	4369550.20	1.5
109	402735.00	4369522.40	1.5
110	402727.00	4369530.60	1.5
111	402744.00	4369565.80	1.5
112	402747.60	4369555.40	1.5

Grid 4 Comparison of the man portable survey to the Robotic.

Notes: Targets are ranked by intensity for the man portable and then compared with the Robotic survey with offset distance shown from the man portable picks. Average offsets were .4 m. Items with intensity below 1.8 are excluded from the manned listing.

Man Portable 5/18/07   RMP 5/18/07

MP Target ID	x	y	ch3	RMP Target ID	x	y	ch3	Distance	Reason not selected
1	402738.40	4369552.40	260.4	4	402738.20	4369552.00	92.6	0.45	
2	402724.00	4369526.00	177.5					*	in gap
3	402726.80	4369545.00	176.9	1	402726.60	4369544.80	154.6	0.28	
4	402756.60	4369558.20	140.5	3	402756.80	4369557.60	101.7	0.63	
5	402733.75	4369558.61	84.0	2	402733.57	4369558.71	102.0	0.21	
6	402714.20	4369504.80	45.2	5	402714.40	4369504.80	44.4	0.2	
7	402753.58	4369534.21	44.1	9	402753.38	4369534.28	33.3	0.21	
8	402747.60	4369562.00	39.6	8	402747.60	4369561.40	37.5	0.6	
9	402730.00	4369528.60	39.0	7	402729.80	4369528.40	38.8	0.28	
10	402746.20	4369543.40	35.3	6	402746.00	4369543.40	39.8	0.2	
11	402750.40	4369567.40	32.9	10	402750.40	4369567.00	31.0	0.4	
12	402748.80	4369550.80	21.2	13	402749.00	4369550.40	14.4	0.45	
13	402744.80	4369536.60	19.4	15	402744.40	4369536.60	13.4	0.4	
14	402733.16	4369531.44	14.2	11	402734.00	4369530.80	17.3	1.05	
15	402710.00	4369497.00	13.7	12	402710.20	4369496.60	15.6	0.45	
16	402754.20	4369563.80	12.6	14	402754.00	4369563.40	14.3	0.45	
17	402738.49	4369542.99	8.6	17	402738.80	4369542.40	8.8	0.67	
18	402719.80	4369506.40	6.6	18	402719.80	4369505.80	6.8	0.6	
19	402735.00	4369542.60	4.4	20	402734.60	4369542.60	5.4	0.4	
20	402757.82	4369541.85	4.2	16	402757.40	4369542.00	9.6	0.44	
21	402753.40	4369565.60	3.9					*	
22	402725.80	4369518.60	3.7	22	402725.80	4369519.00	3.4	0.4	
23	402716.80	4369525.20	3.3					*	in gap
24	402731.40	4369516.60	3.2	30	402731.80	4369516.60	1.7	0.4	
25	402723.30	4369530.63	3.0					*	in gap
26	402744.80	4369529.81	2.9	23	402745.20	4369529.20	3.3	0.73	
27	402715.80	4369521.00	2.8					*	in gap
28	402717.60	4369517.20	2.7					*	
29	402721.00	4369505.40	2.7					*	same as MP18/RMP18

30	402754.40 4369548.00	2.5					*	
31	402753.60 4369552.80	2.4					*	
32	402721.80 4369520.80	2.4					*	in gap
33	402763.00 4369551.80	2.3	25	402763.00 4369551.40	2.8			0.4
34	402718.40 4369504.60	2.2					*	
35	402733.60 4369537.40	2.2					*	
36	402739.80 4369534.80	2.2	31	402739.60 4369534.80	1.6			0.2
37	402728.60 4369541.20	2.2					*	
38	402718.00 4369518.00	2.1					*	
39	402733.60 4369521.00	2.1	28	402733.00 4369520.60	2.1			0.72
40	402723.60 4369544.80	2.1					*	
41	402767.00 4369547.40	2.0					*	
42	402769.40 4369550.80	2.0					*	
			11	402734.00 4369530.80	17.3	*		same as nearby MP14
			19	402769.60 4369554.20	5.9	*		on edge of grid, masked out
			21	402715.03 4369498.52	4.5	*		
			24	402721.20 4369507.00	3.0	*		
			26	402733.00 4369517.80	2.7	*		
			27	402717.20 4369515.20	2.5	*		
			29	402724.00 4369506.40	1.9	*		
			32	402722.60 4369539.60	1.6	*		
			33	402729.00 4369514.40	1.5	*		

* Items not matched

118

Appendix D: Noise Study Report

Appendix E

Noise Study Report

Objective: This project integrates an innovative robotic tow vehicle with industry standard Digital Geophysical Mapping (DGN) sensors and advanced geo-location positioning equipment to autonomously map target demonstration areas. The first phase focuses on integration and path following to precisely replicate geophysical sensor coverage. The first project milestone is to assemble the system and perform a geophysical noise study to determine the affect of the tow system to standard Geonics EM-61 MK II and Geometrics G-858 sensors. Our goal is to characterize the system's effect to establish tow bar lengths and methodology to eliminate or mitigate any noise caused statically by the ferrous components or dynamically as EM fields by the system in motion.

System Description: The tow vehicle is the Segway suite of battery powered vehicles that includes the ATV configurations of the Robotic Mobility Platform (RMP) in the two wheel, RMP 200, and four wheel, RMP 400, as well as the XT two wheel manned vehicle. Positioning for the noise study was provided by fiberglass tape measures and the ArcSecond Laser "Indoor GPS" package that can provide sub-centimeter accuracy for small areas. The RMP is controlled by an on-board lap top computer linked by 802.11g wireless RF modem with a long range rover antenna to the remote control computer. Maneuvering control commands for the noise study from the remote lap top were by keyboard and a standard PC joystick.

Testing Overview: The Noise Study was performed at the Geophysical Test Site at McKinley Range on Redstone Arsenal in Huntsville, AL. It was performed in two categories; as a series of walk away tests from fixed geophysical instrument locations and as a series of profile traverses over a calibration strip. Geophysical equipment included a standard Geonics EM-61 MKII dual coil system used in the towed wheeled configuration and two Geometrics G-858 sensors assembled in a gradiometer configuration with 0.5 m vertical separation on the Geometrics non-ferrous wheeled tow chariot. All equipment was attached and powered up on the tow vehicles to determine affects but not fully integrated. The system was tele-operated by a remote PC joystick control for the noise study.

Walk Away Test: A background geophysical survey was performed to establish a geophysically quiet, anomaly free test area 15 meters in diameter. A baseline was established through the center with spacing of .25 m points for a 4 m length. The geophysical sensor packages were setup with the sensor centered over the baseline zero point with the associated backpacks on the opposite side from the baseline. The test was performed for the EM-61 and then repeated with the G-858. The following individual tests were performed.

1. The base RMP unit was moved at .25 m intervals and the readings recorded with the RMP powered off for both geophysical sensors.
2. This was repeated with the RMP powered up.
3. The video and communication/control system and positioning system were added and the test repeated with power off.
4. This was repeated with all systems powered up.
5. The test was then performed with the complete powered up system moving dynamically under remote control using the positioning system to broadcast position that established offset locations along the baseline. The system traversed the line remotely operated towards the sensor and then away for two complete runs. Speed was at .5 m/sec which gave a dynamic point spacing of less than .1 m.

The data was analyzed and plotted to determine the effect to the geophysical equipment by the robotic tow vehicle system. It was used to identify and help correct noise problems and determine optimum tow bar lengths.

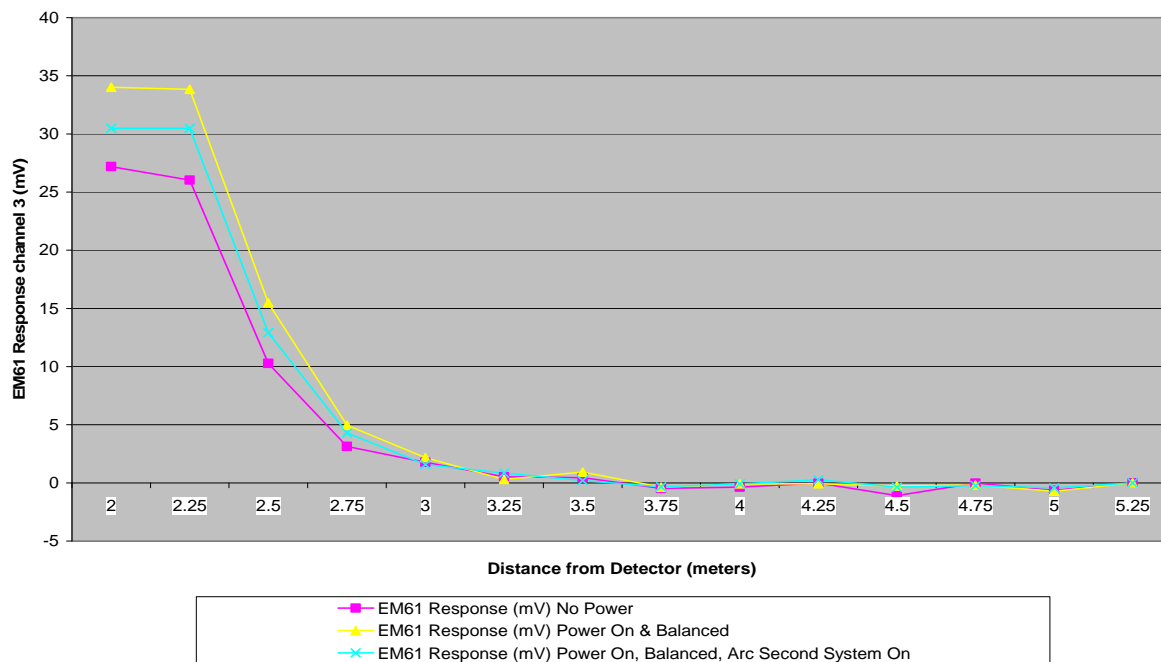RMP 200 testing with the EM

Manned XT testing with the EM

RMP 400 testing with the EM

RMP 400 testing with the Mag

EM61 Walk-A-Way Test with RMP 200 Segway

RMP 200 Offset Distance (m)	EM61 Response (mV) No Power	EM61 Response (mV) Power On & Balanced	EM61 Response (mV) Power On, Balanced, Arc Second System On
2	27.2	34.02	30.49
2.25	26.04	33.84	30.49
2.5	10.28	15.47	12.91
2.75	3.13	4.97	4.3
3	1.78	2.18	1.57
3.25	0.53	0.3	0.84
3.5	0.45	0.92	0.19
3.75	-0.46	-0.36	-0.33
4	-0.36	-0.08	-0.08
4.25	-0.02	-0.07	0.27
4.5	-1.09	-0.27	-0.37
4.75	-0.02	-0.19	-0.24
5	-0.64	-0.72	-0.44
5.25	0	0	0

EM61 Walk-A-Way Test with RMP XT Segway
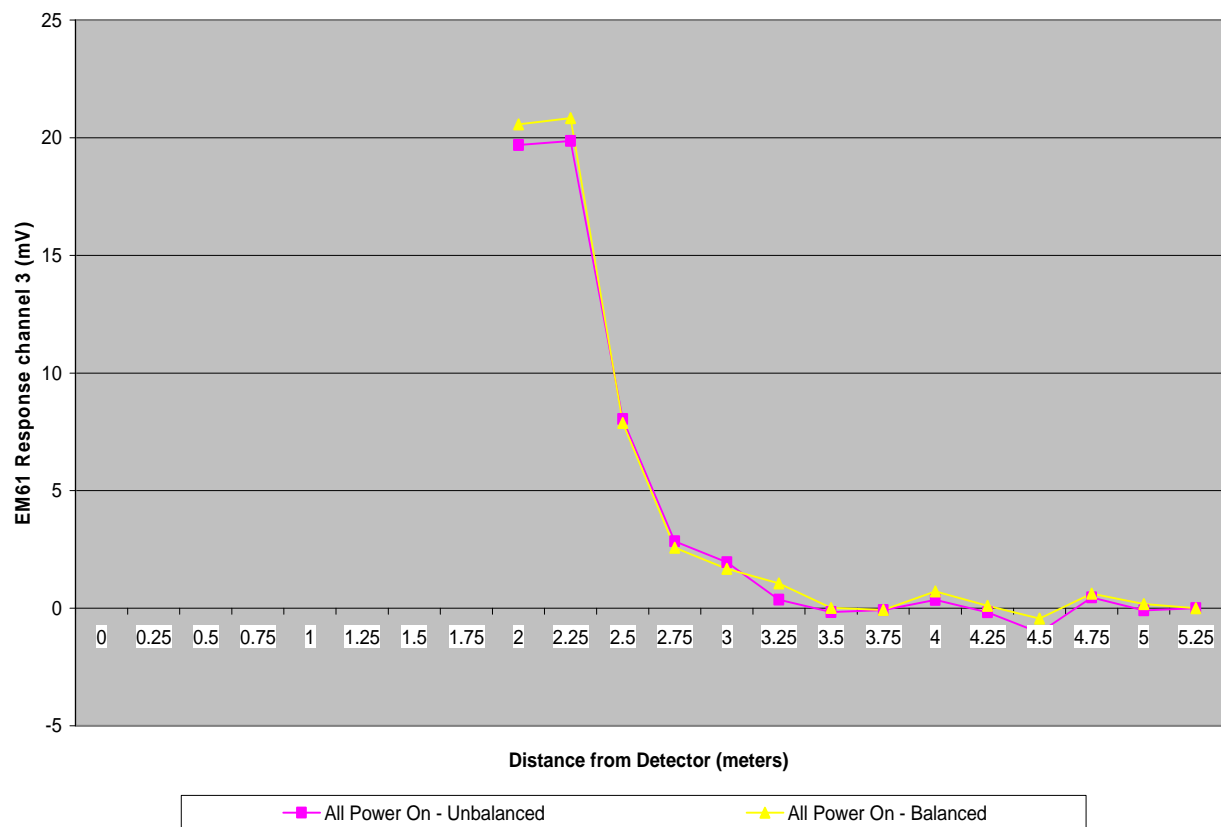
XT Offset Distance (m)	EM61 Response (mV) All Power On - Unbalanced	EM61 Response (mV) All Power On - Balanced
2	19.69	20.57
2.25	19.86	20.84
2.5	8.04	7.88
2.75	2.84	2.57
3	1.95	1.68
3.25	0.36	1.06
3.5	-0.16	0.01
3.75	-0.08	-0.07
4	0.35	0.71
4.25	-0.17	0.1
4.5	-1.04	-0.44
4.75	0.46	0.62
5	-0.09	0.18
5.25	0	0

Magnetic Effect of Steel Axles on RMP 400 Segway with Power On and Off
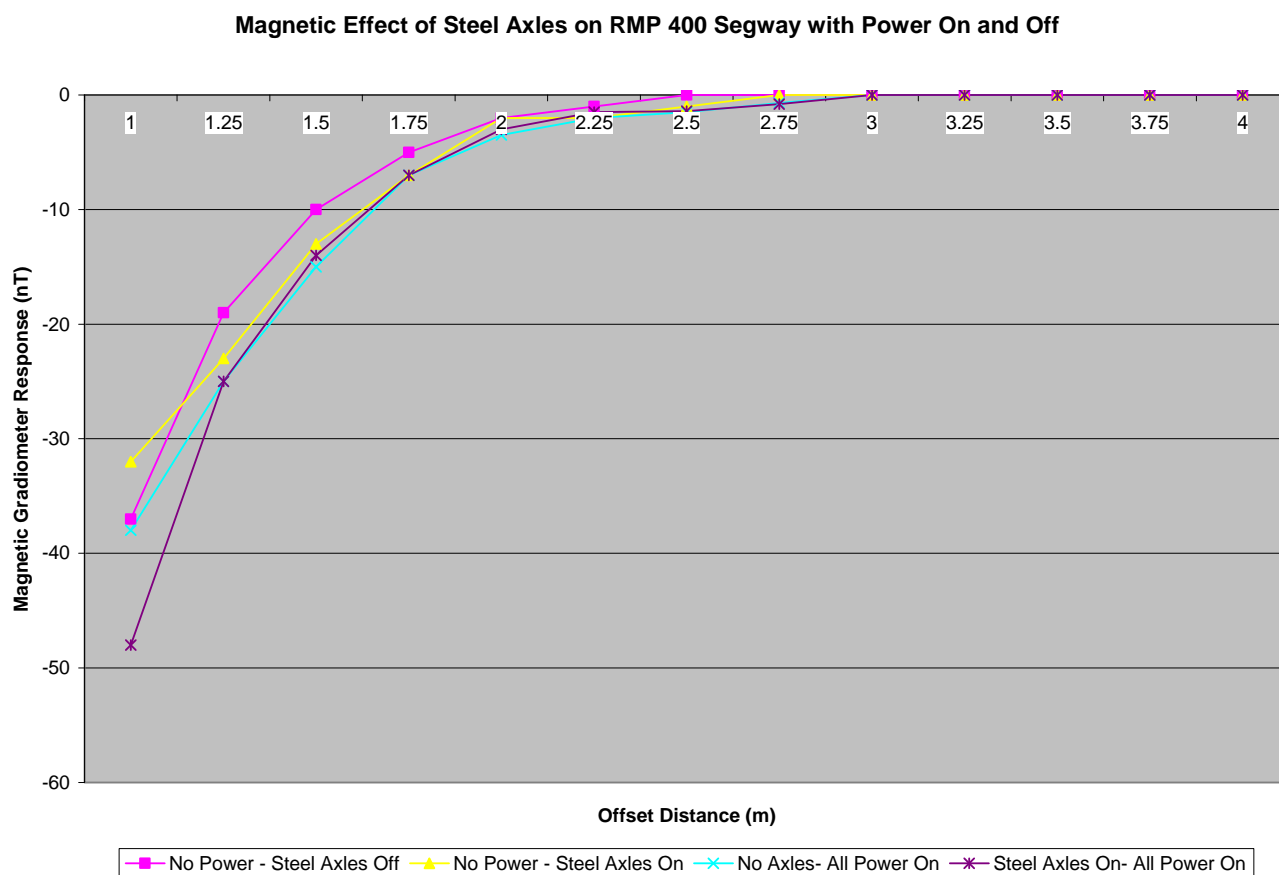
RMP 400 Offset Distance (m)	No Power - Steel Axles Off	No Power - Steel Axles On	No Axles- All Power On	Steel Axles On- All Power On
1	-37	-32	-38	-48
1.25	-19	-23	-25	-25
1.5	-10	-13	-15	-14
1.75	-5	-7	-7	-7
2	-2	-2	-3.5	-3
2.25	-1	-2	-2	-1.5
2.5	0	-1	-1.5	-1.4
2.75	0	0	-0.7	-0.8
3	0	0	0	0
3.25	0	0	0	0
3.5	0	0	0	0
3.75	0	0	0	0
4	0	0	0	0

Comparison of Segway Models XT, RMP 200, and RMP 400 on Magnetic Gradiometer with Distance
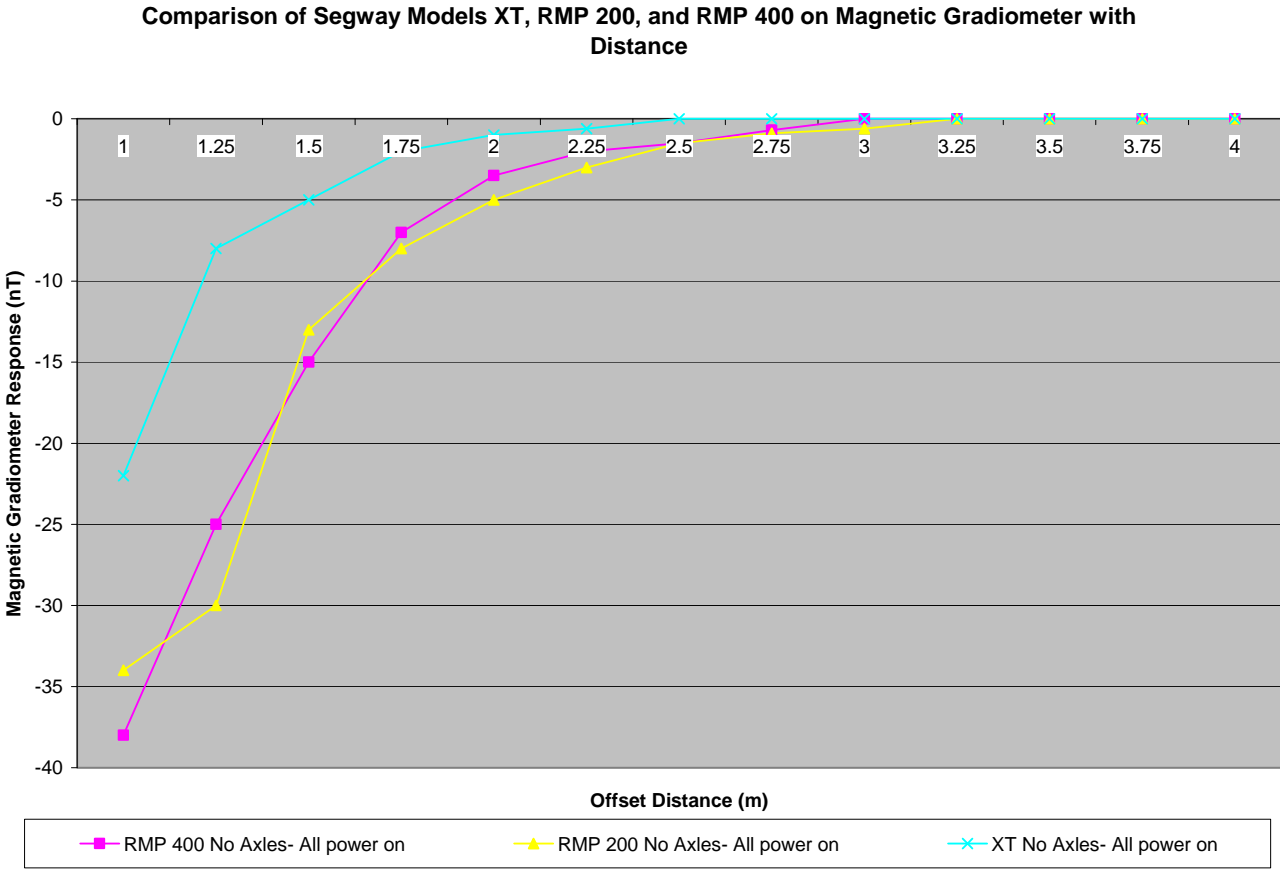
Offset Distance (m)	RMP 400 No Axles- All power on	RMP 200 No Axles- All power on	XT No Axles- All power on
1	-38	-34	-22
1.25	-25	-30	-8
1.5	-15	-13	-5
1.75	-7	-8	-2
2	-3.5	-5	-1
2.25	-2	-3	-0.6
2.5	-1.5	-1.5	0
2.75	-0.7	-0.9	0
3	0	-0.6	0
3.25	0	0	0
3.5	0	0	0
3.75	0	0	0
4	0	0	0

The tow bar lengths of 3.25 m from the center of the EM-61 coil to the rear of the Segway and 3.0 m from the G-858 magnetometer sensor to the rear of the Segway as determined by the Walk Away Testing

Azimuth Test: With the G-858 at the center point, readings were taken with the tow vehicle system at 2.5 m, 2.0 m, 1.5 m and 1.0 m spacing from the sensor. The tow vehicle was then rotated about the center point in 45 degree azimuths and the readings repeated until the sensor and tow vehicle has been rotated back to the starting baseline. The data will determine the magnitude and direction of the associated magnetic heading error as introduced by the tow vehicle system.
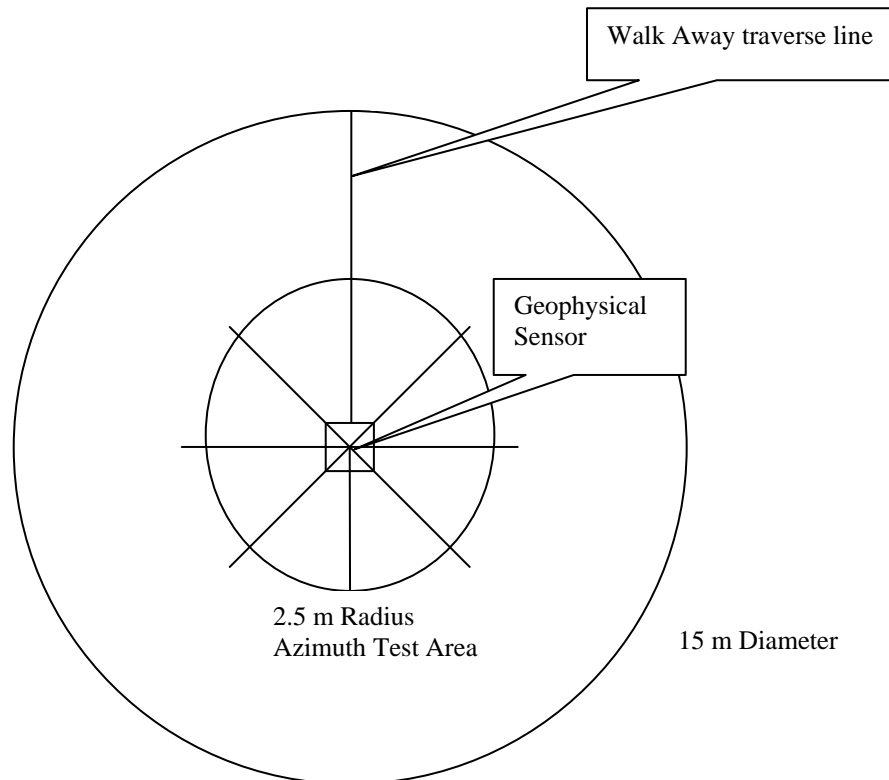
Figure 1- Walk Away Test Area

Heading Error Results for G858 Magnetic Gradiometer and RMP 200 Segway
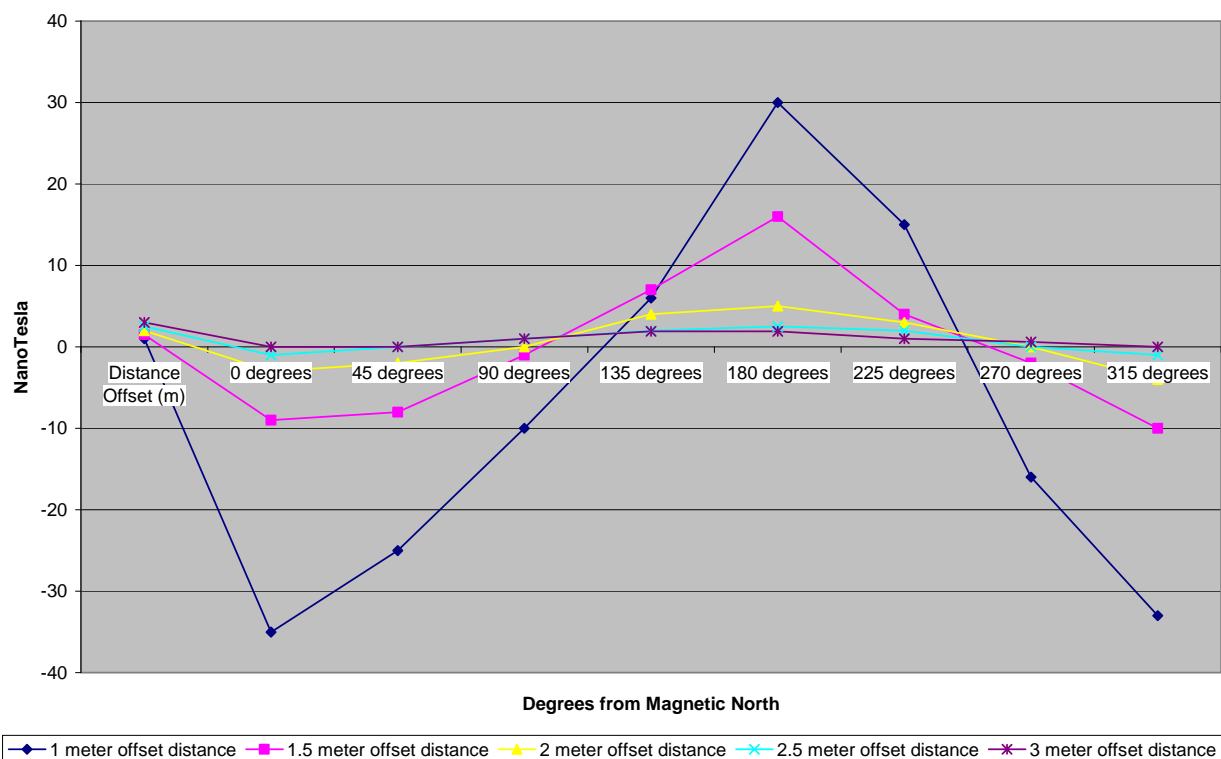
Heading Error Results for G858 Magnetic Gradiometer and RMP 200 Segway

Distance Offset (m)	0 degrees	45 degrees	90 degrees	135 degrees	180 degrees	225 degrees	270 degrees	315 degrees
1	-35	-25	-10	6	30	15	-16	-33
1.5	-9	-8	-1	7	16	4	-2	-10
2	-3	-2	0	4	5	3	0	-4
2.5	-1	0	1	2	2.5	2	0	-1
3	0	0	1	1.9	1.9	1	0.6	0

Heading Error Results for G858 Magnetic Gradiometer and RMP 400 Segway

Legend: ◆ 1 meter offset distance ■ 1.5 meter offset distance ▲ 2 meter offset distance ✕ 2.5 meter offset distance ✳ 3 meter offset distance
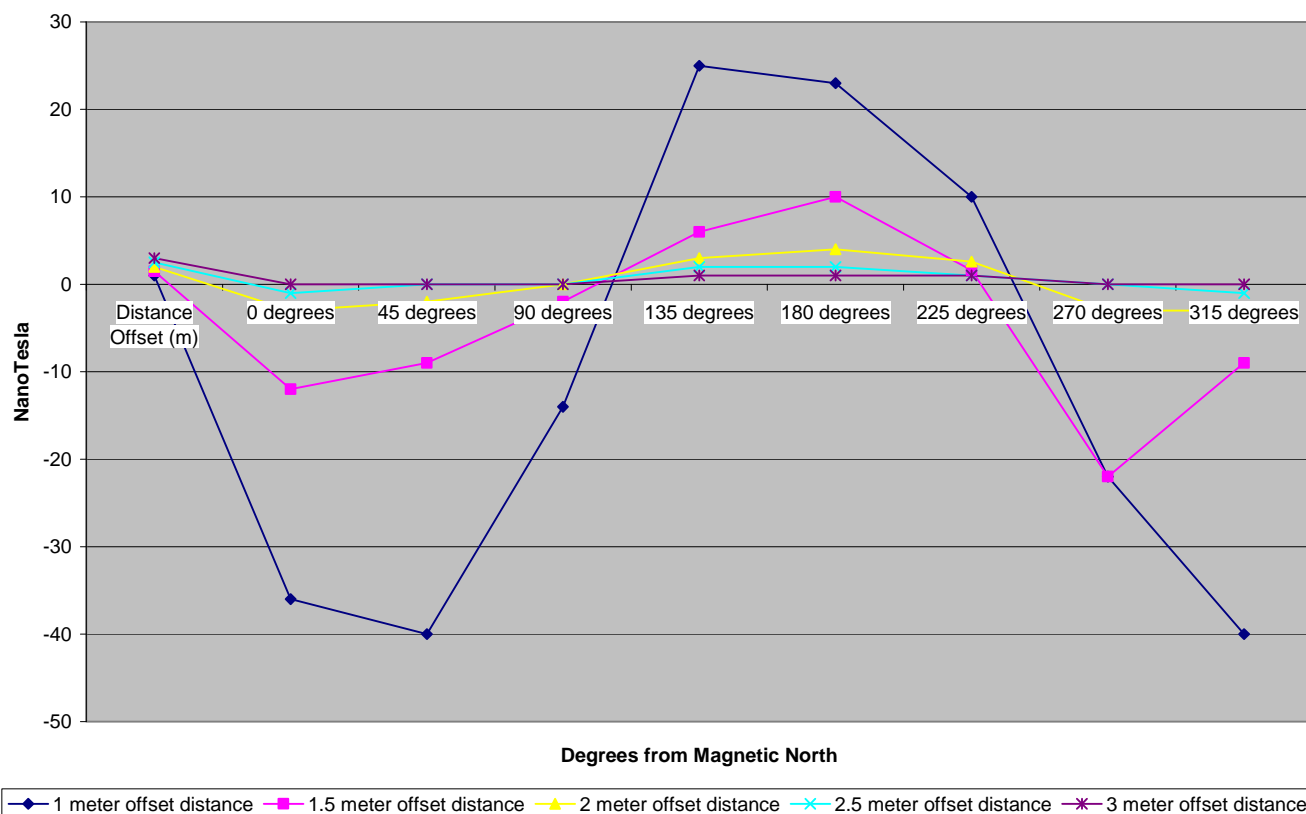
Heading Error Results for G858 Magnetic Gradiometer and RMP 400 Segway

Distance Offset (m)	0 degrees	45 degrees	90 degrees	135 degrees	180 degrees	225 degrees	270 degrees	315 degrees
1	-36	-40	-14	25	23	10	-22	-40
1.5	-12	-9	-2	6	10	1.6	-22	-9
2	-3	-2	0	3	4	2.6	-3	-3
2.5	-1	0	0	2	2	1	0	-1
3	0	0	0	1	1	1	0	0

Azimuth Heading Test Results in nanoTesla at 2.5 meters distance
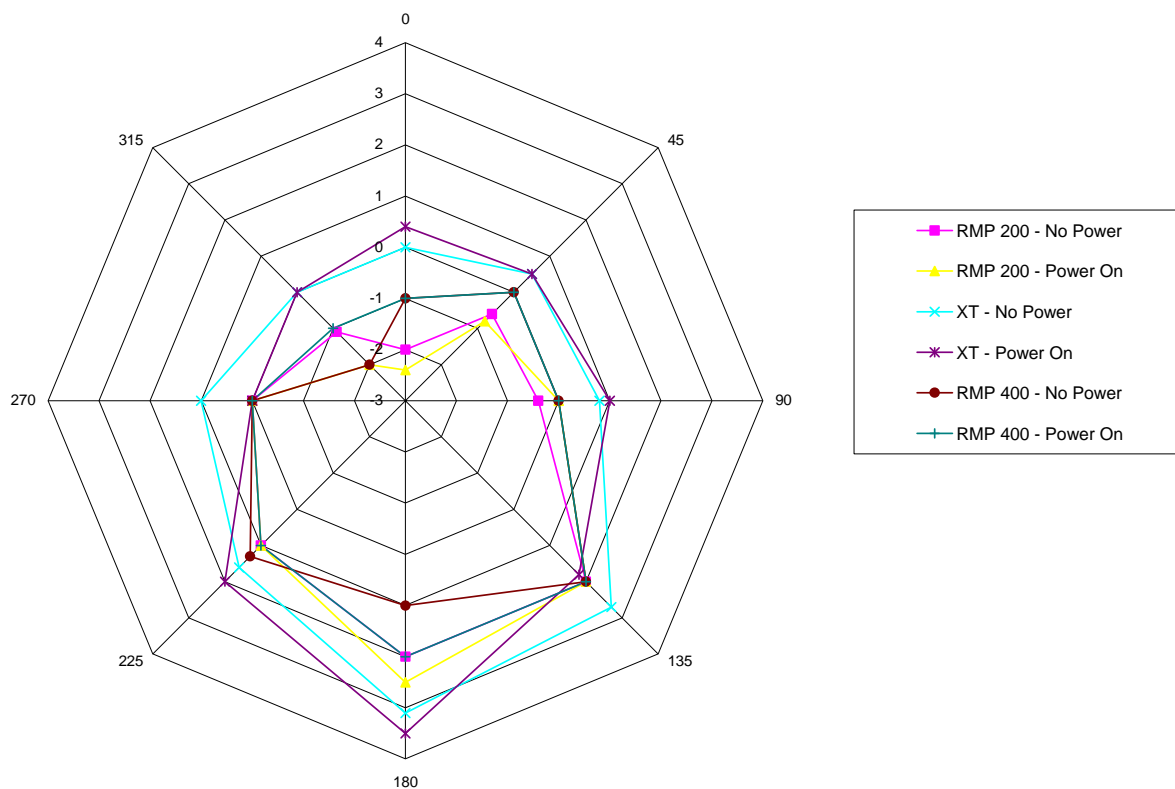
Azimuth Heading Test Results in nanoTesla at 2.5 meters distance

Azimuth Angle (degrees)	RMP 200 - No Power	RMP 200 - Power On	XT - No Power	XT - Power On	RMP 400 - No Power	RMP 400 - Power On
0	-2	-2.4	0	0.4	-1	-1
45	-0.6	-0.8	0.5	0.5	0	0
90	-0.4	0	0.8	1	0	0
135	2	2	2.7	1.8	2	2
180	2	2.5	3.1	3.5	1	2

Calibration Strip Testing: A 60 m calibration strip was established in an E-W orientation in a geophysically clean area north of the existing test grids. The ArcSecond positioning system was setup using the existing grid's surveyed in corner points to establish positioning in UTM metric coordinates. This system along with cloth tapes and tick wheel counters was used for geophysical survey positioning over the Calibration Strip. The area was mapped for the baseline background by the same EM-61 and G-858 geophysical sensors but in the man towed configuration prior to seeding. Existing anomalies were avoided during the seeding operation. Seed locations were marked at 5 m intervals for 12 holes. 3 sets of 4 holes were dug to a .15 m, .25 m and .05 m depth. Each set was seeded with a 3# practice bomb with one orientated nose down, one horizontal at N-S orientation, one horizontal at a W-E orientation and one at a 45 degree dip in an W-E orientation. Once seeded the strip was again mapped with the man towed geophysical sensors to establish the seeded baseline.

Pre-Seed background Survey Results
3 lb Practice bomb Area
McKinley Range June 20, 2007
Processed by R.J.Selfridge

Anomaly avoidance targets

X	Y
1.49154252771	39.7738240111
0.741690348577	123.382064093
4.86587101523	139.128918397
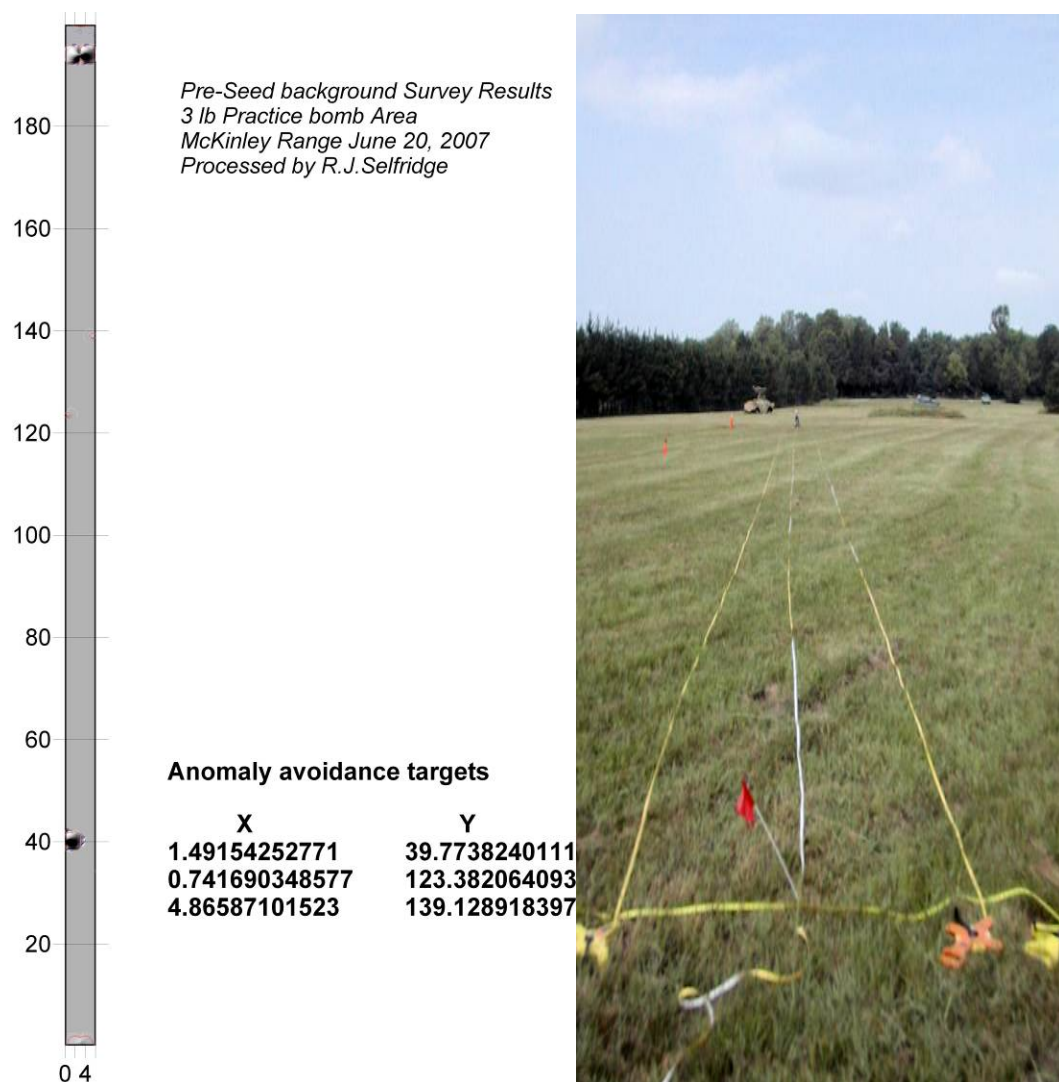
Calibration Strip

Calibration Strip 3# Practice Bomb Seeds				
Item #	Baseline Range	Orientation	Depth	
rebar	0			
1	5	N-S	0.15	
2	10	W-E	0.15	
3	15	45 dip W-E	0.15	
4	21	nose down	0.15	
5	25	N-S	0.25	
6	30	W-E	0.25	
7	35	45 dip W-E	0.25	
8	40	nose down	0.25	
9	44	N-S	0.05	
10	52	W-E	0.05	
11	55	N-S	0.05	
12	60	E-W	0.05	
Rebar	61			

Practice Bomb Vertical Orientation

Table of Seeded 3# Practice Bombs

Practice Bomb N-S orientation

The calibration strip was traversed with the robotic tow vehicle towing the two sensor packages with the tow bar length of 3.0 m from the rear of the Segway and 3.0 m from the G-858 magnetometer sensor to the rear of the Segway as determined by the Walk Away Testing. The test were performed with the complete powered up system dynamically under remote control using the positioning system to broadcast position and establish the offset locations along the baseline. The system traversed the line remotely operated in the W-E direction at different speeds. Speed was held constant at the following rates: 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 mph as demonstrated in the attached plots for the RMP 400.
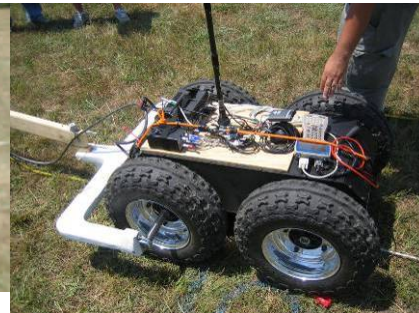
RMP 200 with EM-61 MKII

RMP 400 with EM-61 MKII
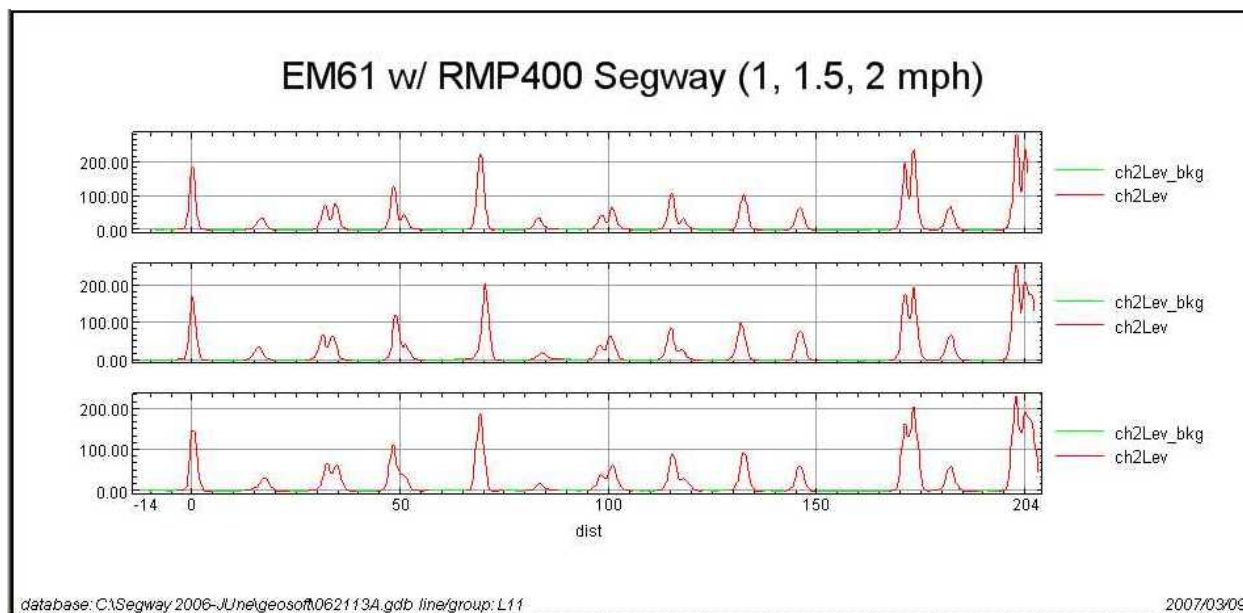
RMP 400 with G-858 Magnetometer
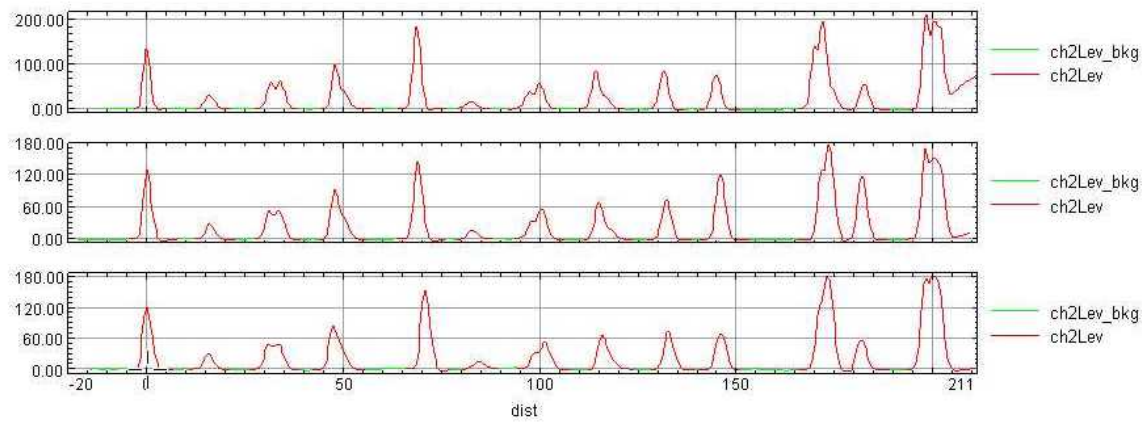

Manned XT with EM-61

Man towed EM-61

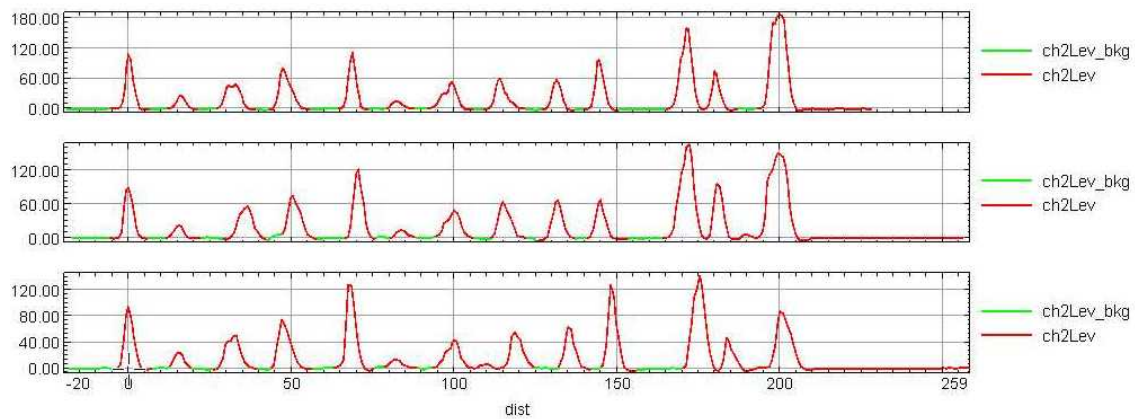Man towed G-858 Magnetometer

EM61 w/ RMP400 Segway (2.5, 3, 3.5 mph)

database: C:\Segway 2006-JUne\geosoft\062113A.gdb line/group: L14   2007/03/09
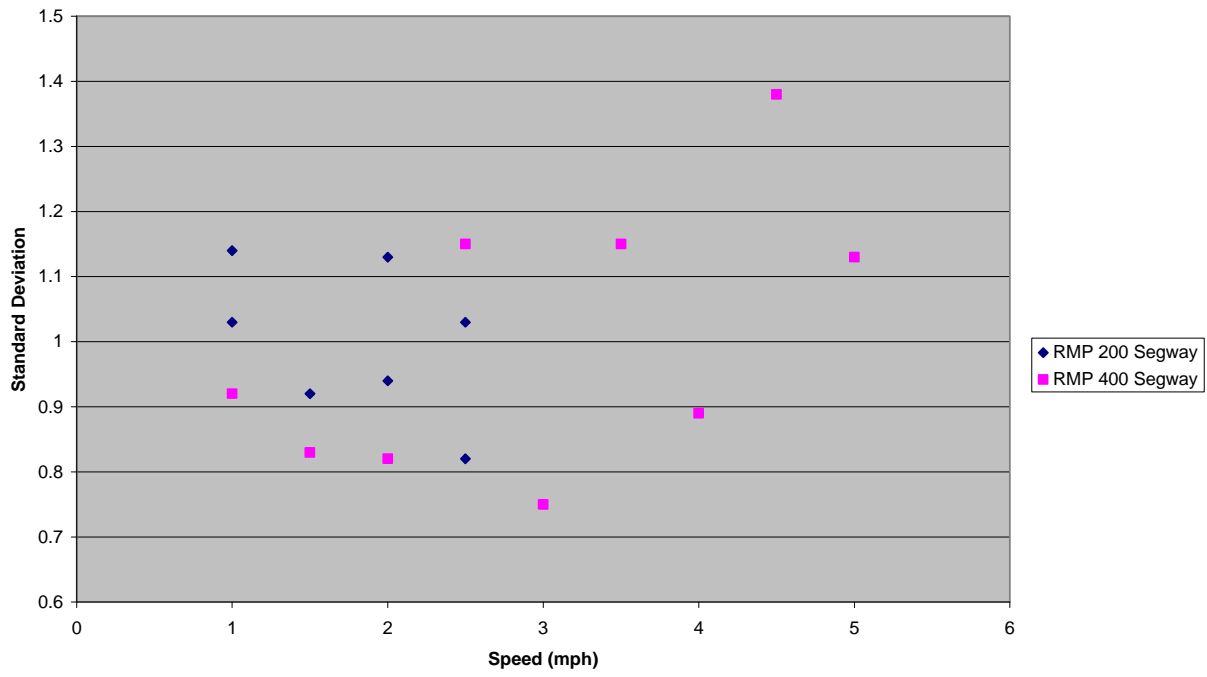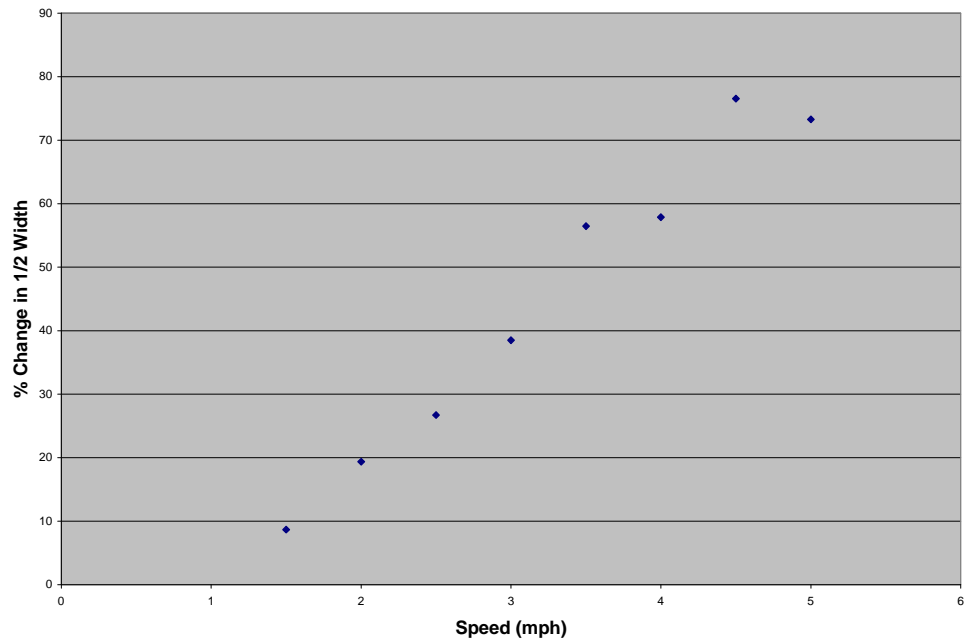

EM61 w/ RMP400 Segway (4, 4.5, 5 mph)

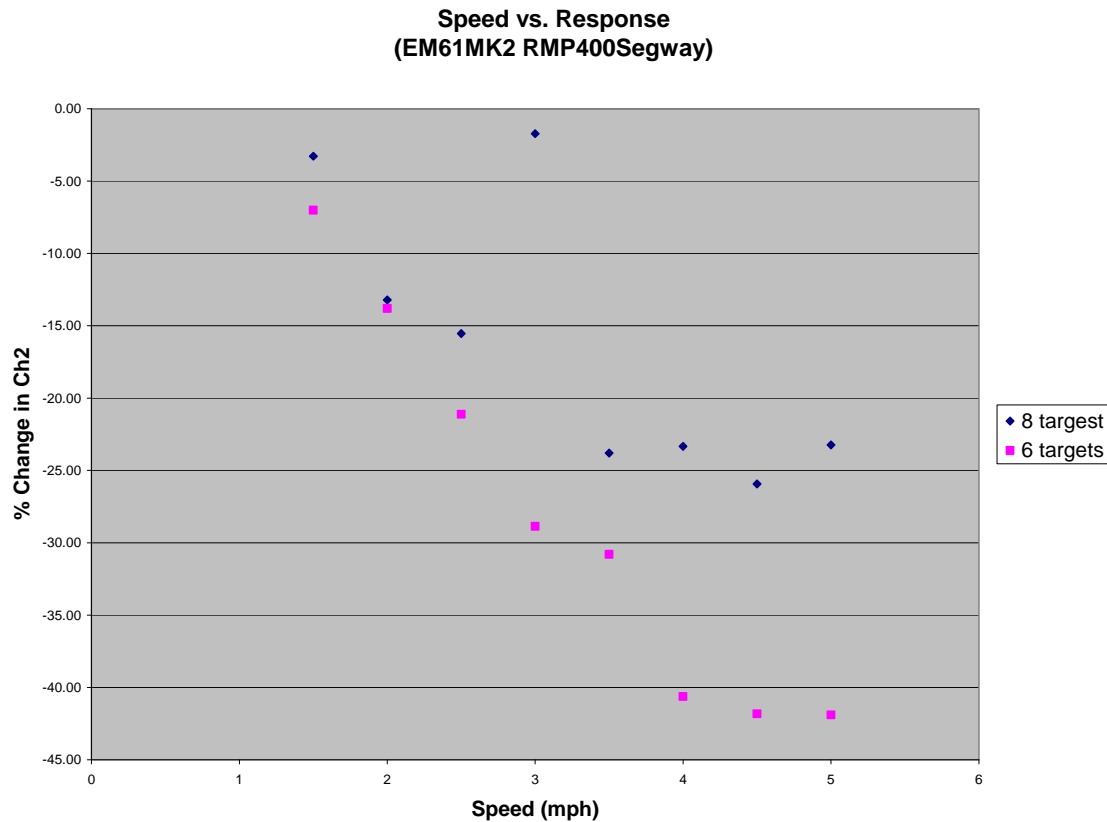database: C:\Segway 2006-JUne\geosoft\062113A.gdb line/group: L18   2007/03/09

134

Background Noise (EM61MK2, Ch2)

**Speed vs. Size
(EM61MK2 RMP400Segway)**

**Speed vs. Response
(EM61MK2 RMP400Segway)**

Noise Study Conclusions:

The standard deviation for background noise produced versus speed and anomaly half width and maximum response change with respect to speed indicate that the reduction of all these parameters are relatively insignificant with the XT and RMP 400 platforms. Even at the maximum of 5 mph, the data response is not adversely affected, but it was observed that this was the maximum speed for the existing platforms from a materials durability aspect.

The RMP 200 can not maintain a constant speed due to terrain variations. Unlike a human it can not anticipate and adjust tilt. The abrupt speed variations dramatically degrade data quality. Correcting this defect is currently outside the scope of the project. We will focus on the RMP 400. The noise study showed an increased tow bar length need for the robots compared to the previous years feasibility testing. This was subsequently found to be caused by a change in product design that included adding a steel protective case surrounding the electronics package of the Segway units, a higher capacity internal charger and the steel axle stub shafts. These noise sources were minimized after reviewing the results of this testing by replacing the steel axles with brass stub shafts, substituting the original versions aluminum protective case for the current models steel one and removing the charging system to an external configuration that is no longer integral to the Segway.